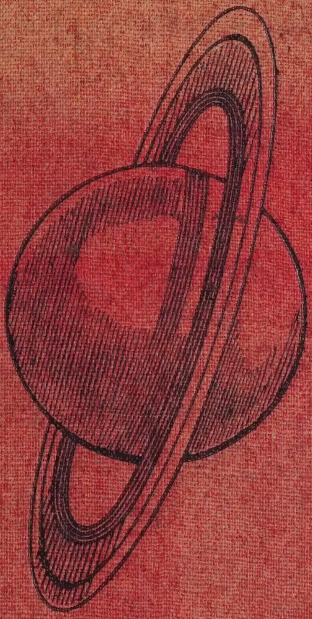
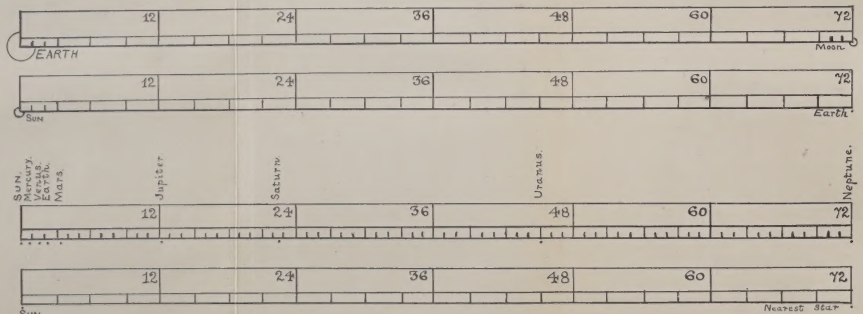
THE ROMANCE OF THE SKY



C. J. GRIFFITH

THE ROMANCE OF THE SKY

MEASURING THE HEAVENS with a SIX FOOT RULE.



RULE Nº 1.		RULE Nº 2.		RULE Nº 3.		RULE Nº 4.	
One Eighth:	413 Miles	One Eighth:	159,722 Miles	One Eighth:	5,034,722 Miles	One Eighth:	34,722,222,222 Miles
One Inch:	3,305 "	One Inch:	1,274,777 "	One Inch:	40,277,777 "	One Inch:	277,777,777,777 "
72 Inches:	238,000 "	72 Inches:	92,000,000 "	72 Inches:	2,900,000,000 "	72 Inches:	20 BILLION "

C. J. GRIFFITH.

THE ROMANCE OF THE SKY

THE STORY OF STAR-GAZING AND STAR-TRACING, BEING AN INTRODUCTION TO THE STUDY OF ASTRONOMY

BY

C. J. GRIFFITH

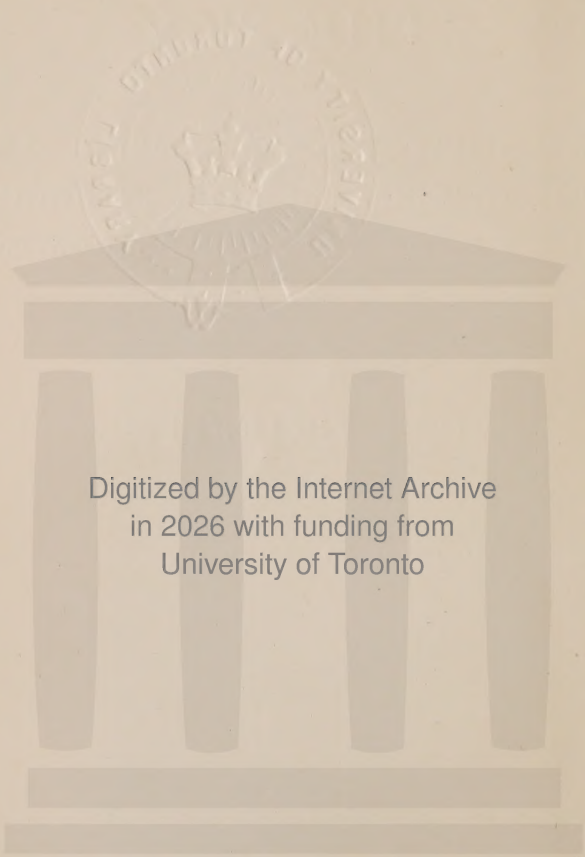
ILLUSTRATED BY THE AUTHOR

95822
3/6/89

LONDON

GEORGE ROUTLEDGE & SONS, LIMITED

NEW YORK: E. P. DUTTON & CO.


Digitized by the Internet Archive
in 2026 with funding from
University of Toronto

https://archive.org/details/romanceofskystor00grif

PREFACE

IT is hoped that in the following pages there will be found an easy and pleasant introduction to the Science of Astronomy. It is to be feared that many persons nowadays know less of the constitution of Nature than did the pastoral races of bygone times. Knowledge of the heavens above and of the earth beneath is as truly 'dead' to the many, as the Greek and Latin tongues so assiduously taught in our foremost schools. Yet is there a fascination in both studies to all those who are willing to pass the threshold.

Especial care has been taken to show how from age to age knowledge has accumulated; how human genius has striven and conquered; how one by one the labourers ceased, having added their quota to the general store, as others entered into their labours. The pardonable expedient has been adopted — not claimed in any wise as original — of one IDENTITY and one MIND, speaking through the whole, as if present at each acquisition of fact.

The writer hopes that many a reader, dissatisfied with having learned so little, will turn from this to larger works, with such zest as this booklet may haply inspire.

CONTENTS

CHAP.		PAGE
I.	FIRST IMPRESSIONS	1
II.	A TALK WITH PTOLEMY	5
III.	COPERNICUS PUTS US RIGHT—A REACTION	11
IV.	KEPLER PROPOUNDS HIS TWO LAWS	16
V.	GALILEO AND HIS MAGIC TUBE; AN ALTERCATION AND A TRIAL. THE LAWS OF MOTION	20
VI.	MEETING OF GALILEO AND KEPLER. THE THIRD LAW OF PLANETARY MOTION	26
VII.	REMINISCENCES. THE DISCOVERY OF THE BAROMETER	33
VIII.	NEWTON DISCOVERS THE LAW OF UNIVERSAL GRAVITATION; THE MAINSPRING OF THE UNIVERSE	37
IX.	PROF. HALLEY PROPOSES A PLAN TO MEASURE OUR DISTANCE FROM THE SUN	43
X.	I CONSTRUCT A PRIVATE OBSERVATORY	51
XI.	A LECTURE ON THE SOLAR SYSTEM; AN EXTRAORDINARY ANNOUNCEMENT	57
XII.	HERSCHEL SHOWS ME SOME DOUBLE STARS AND THE PLANET URANUS	66

CHAP. PAGE

XIII. BODE'S LAW; NAMING URANUS; A NEW FIND; THE NODE 71

XIV. HOW TO TELL THE STARS BY THEIR NAMES . 74

XV. THE DISTANCES OF THE STARS AND HOW ASCERTAINED; APPARENT FIXITY—REAL MOTION . 85

XVI. DISCOVERY OF THE PLANETOIDS: ADAMS, AND THE DISCOVERY OF NEPTUNE 90

XVII. CONCERNING THE PLURALITY OF WORLDS, AND THE NEBULAR HYPOTHESIS 95

XVIII. A DISSERTATION ON TIME 101

XIX. LONGITUDE, LATITUDE, THE *NAUTICAL ALMANAC*, THE MOTION OF LIGHT, ETC. 105

XX. A FEW WORDS ON VELOCITY—QUICK AND SLOW 112

XXI. A BUDGET OF ODDMENTS AND A VOTE OF THANKS 118

XXII. AFTER THE BUDGET 127

XXIII. DIFFICULTIES ONE HAS TO OVERCOME. . . 133

XXIV. SOME ASTRONOMICAL TERMS. ITEMS FROM NOTE BOOK ARRANGED IN THE FORM OF A GLOSSARY 138

XXV. MEASURING THE HEAVENS WITH A SIX-FOOT RULE 148

INDEX 159

THE ROMANCE OF THE SKY

A STORY OF STAR-GAZING AND STAR-TRACING

CHAPTER I

FIRST IMPRESSIONS

An Astronomer need have a very long life to make any progress in the science of the Universe; a generation, a century, or even a thousand years are altogether too short. I doubt if Adam, with all his 930 years, was more than simply mystified with the movements of the heavenly bodies.

Of course, by the time I seriously commenced thinking of the matter, a great deal was commonly known. Sages for many years have noted marvellous truths concerning the constitution of nature, the inheritance of which was mine, one might say, from my earliest schooling. For instance, we knew exactly from behind which hill the sun would rise in the spring, and from what other parts he would appear at the different times in the year, and also where he would set in the West in the cool of the evening. And it was noted that although he never rose or set in the same place any two days, the marvellous thing was, that when spring-time came again, the positions of the previous year were resumed by him to an exactness, the most embarrassing.

The moon did much the same, but was more erratic. The youths and maidens of the time thought not much of these things, but those given to reflection

pondered deeply on the unfathomable. Why, for instance, should the moon be continually changing her shape?—So much so, and so regularly, that the current saying 'From Moon to Moon' served to divide our time—yet did the sun maintain his roundness always. But to be correct, and this thought has just come to me, it occasionally happened that the sun even became a crescent, though very rarely; such happenings causing us no small dismay, nor us only, for even the flocks and cattle seemed afraid he might be blotted out and never return with his full light and heat. Happily the occurrence was most rare, and hitherto the danger has passed by all right.

It was a source of great comfort to me after the toil of the day, to contemplate the stars, those very small points of light, that served to make the night so enjoyable when the moon, as well as the sun, was absent. Their silent majesty! And yet so small! So numerous too! It seemed to me they never could be counted! What marvellous machinery held them in their places, and escorted them so regularly around our earth?

My then friend, with whom I often conversed, asked me how far off I thought them. How far! Ah! Who could tell?

Our country was large, how large nobody knew. No traveller had ever been to the confines where sky and land met, or if so none ever had returned. Certainly many a day's journey which few could brave. But the fact remained that the sun and all the host of Heaven encircled the whole expanse every day. What food for thought was there! From the everlasting snows to the burning desert; or from the lands beyond the Caspian to the Isles of Albion were a vast expanse. If the land (and water) were 5,000 miles in each direction, and it could hardly be less, the heavens must be at least as high. So we reckoned they all must travel in the course of one day and one night at least 30,000 miles! But, as I said, the common folk interested themselves not in these grand facts of nature.

Of course, I never gave heed to the popular fallacy about the earth resting on an elephant, and the elephant upon a tortoise. That was a myth that suited well for a tale. There must of course, thought I, be a proper provision for the under circuit, between the land we dwelt upon and the Great Underneath. And immense indeed must be the supports that maintained the earth so securely.

A curious thing happened one day, I well remember. We were journeying home, my friend and I, in the early evening, the sun was setting in the West after a glorious day, and in the East the moon was just above the horizon. It appeared unusually large in the slight mistiness that prevailed, as happens often at harvest-time, and general attention was directed to her. And while we looked there appeared as though a huge plate, or it might be another larger moon, only a black one, was steadily creeping across her face. We were all very much awed by the sight. Not that we had never seen the like, only it was generally when the moon was high, but now being low down, we could hardly refrain from the thought that the sun just setting, was casting our shadow upon her; but that on second thought it hardly could be, for as I said the creeping thing was not square or flat, but round as the moon herself. However, it afforded gossip for many a day. We were not long without another sensation, although it affected only those who were of the educated classes.

You are well acquainted with the general appearance of the stars, how some are very bright, others less bright, and many others quite faint. And as they journeyed in company it was our pleasure to note certain curious figures they appeared to resemble in their various groupings, such as a bear, a lion, a hunter with belt and sword, and so forth, and indeed we gave them these several names. One night whilst watching a particularly bright star, and admiring its splendour, one of our company startled us with a remark, coupled with his serious manner, 'Brothers', said he, 'I do not pretend to know the reason, but

certain I am that that star is different from all others —it is moving on its own account.'

Eager for information we demanded what he meant: 'I am certain', he continued, 'it was nearer that faint star, its neighbour, a few nights since; I noticed how ill-sorted they appeared, and now he's wandering away.'

'Oh! The Wanderer!' we all exclaimed, and by that name we knew that star henceforth, and we debated if he might not be another moon that might draw nearer and get larger by degrees.

When the excitement of this discovery tamed a bit, as is always so after a short lapse of time, one of our number suggested we should set ourselves to mark if any others affected a path of their own. It was slow work, but our reward in truth was great, for two if not more were distinctly noticed, and then we made ourselves a trap, as it were, to catch them. We drove a tall stake into the ground, and a second one some distance off, connecting the two with a hempen cord. To this cord we appended certain white linen rags, and while one watched from a distance, another adjusted these rags, until they agreed with two or more stars. What was our surprise when we noticed after several nights that the one we suspected had moved nearer by half to another star, and as much farther from a third; but we were still more puzzled later, when we found the moving one had begun to retrace his path, but in a few weeks' time he sallied away again. 'Oh uncertain, and erratic ones', we exclaimed, 'will it be possible to solve some day the meaning of these portents?' And our wonder continued! We estimated what sizes they severally were, and what their distances; but while we wondered we sustained a big shock, for one night late in the autumn whilst sitting in company at our tent door, we were astonished at a marvellous sight! Countless stars were hurtling across the sky, with terrific speed, and we saw next morning in my cousin's farm a short distance off, one that had fallen, cold and irony. It had half buried itself in the soft earth

and was fully the size of a large tent and weighed more than two score of men. But how had our conceptions of size diminished; and when, alas! would the other stars disappear also!

CHAPTER II

A TALK WITH PTOLEMY

To speak 'as we know' is the boast of some people —it would be safer to say we speak as we *think* we know. It may be taken as a truism that what was accepted as truth yesterday is proved to be false to-day. Doubtless, knowledge will accumulate and become positive as the generations pass.

The ancients might well be excused for their many erroneous conceptions. *They* were seeking light in the darkness, with *us* the day had begun to dawn.

I never was more delighted than when that great man of science, Claudius Ptolemæus, favoured me with a number of interviews, the while he spread before me so much of the book of nature, in deep but entertaining converse.

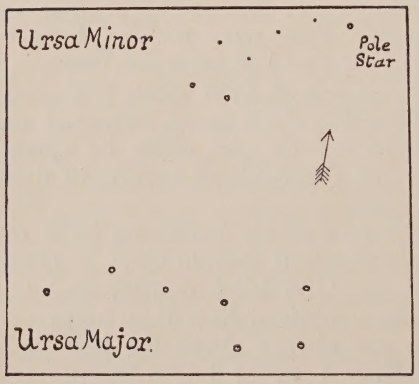
Taking me to the roof of his house, he bade me observe well the constellations then in view. 'Those seven stars', he began, 'the hind quarter and tail of the Bear; hast thou noticed how they never set, but day and night are always above the horizon?' I replied that certainly I never had observed the heavens and not seen them. 'Look now', he went on, as he pointed towards the South, 'there is Orion, certainly the most beautiful sight in the heavens; for about half the year we watch the stars in his group, but for the remainder of the year we never see them, they set as does the sun. Opposed to this there is a star, not far removed from the Bear, that is practically fixed, a point only, a sort of pole or axis that all other stars obey as the central one, and around which they circle in their appointed paths. In this

matter we must observe that all the stars move with a different rate of progression, according to their distance from the central one, but they all complete their several journeys in exactly the same time, that is, in one day. The stars that lie nearest the central one move slowly, those farthest off with a terrific speed!'

'What mean you by "terrific speed" my father?' I exclaimed; 'they all appear alike at rest?'

'Just think', he continued, 'the two innermost stars in the Bear, away from the tail describe a circle in twenty-four hours; it is a small circle because they are near to the central one. Indeed, a line drawn from star to star and continued, points almost exactly to the central star of which I speak.' And while speaking he produced this diagram.

'And you will notice that the stars in the tail are farther off from the central one, and so must describe a larger circle, but as I told you, they each complete their journey in precisely the same time, the larger the circle the quicker the motion; and verily, those farthest off must move with a terrific speed.'



An exclamation escaped me, but he went on: 'The central star is not central to us, that is it is not in the zenith, or overhead, nor is it on the horizon, but nearly a third part of the heavens below the zenith. It follows therefore that Orion, and the stars farthest off, *dip* below our earth in the course of their journey, whilst those that are nearer never *dip*.'

'I think I understand', I remarked, 'but did you not say, that for half a year, we do not see Orion, and yet they perform the journey in twenty-four hours?'

'True, I did; I will explain', he continued. 'It appears that the whole mass of stars rise a little earlier on each succeeding evening, and in the course of a year, this accession of time in rising coincides to complete a circle of the heavens in a year; so that in any one season in any year, or rather any one day in one year, and the same day in another year, we see the stars in the position proper for that day. In consequence, the stars at a distance from the central one will be in the firmament at night, and therefore visible say in the winter; but half a year later, they will be in the firmament in the daytime and we shall not see them.'

'I am deeply interested in these things', I declared, 'and profoundly impressed, but how, or why do the heavenly bodies move thus, as it were, on the skew, and not at right angles as we might expect?'

'Right angles, my son', said my venerable tutor, 'is hardly the term for circular motions; but I perceive you enter into the spirit of our enquiries. The "why and wherefore" is beyond our apprehension. We see the orderings of an Almighty power, and it may be that future discoveries will make these wonders plain.'

'If you can follow me, I would like to confide to you my thoughts on the constitution of our earth. The contemplation of nature enlarges our ideas, and oftentimes compels us to renounce old and cherished beliefs. I am forced to conclude that the earth we call our own is not the *plane* our fathers declared it to be, but a large round ball, of immense size, and as truly a globe as the sun, or as the moon is, that lights our night.'

I was too astonished to speak, and Ptolemy himself sat silently gazing into space as though to give time for reflection. Presently he resumed:

'I do not perceive in what manner its stability is assured, but the Earth is a globe, and all the heavens above—the sun, the moon, the stars and planets,

pursue their endless journeys around us, and we finite creatures, on the only fixed and steady platform in nature, fail to apprehend.'

After another prolonged silence he bade me repair to his house on the next evening, when he would instruct me in other wonderful truths, and I bade him an affectionate farewell.

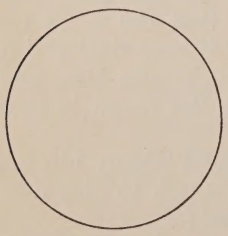
* * *

On the day following, I had a message asking me to defer my visit till the next morning; so about two hours after sunrise on the appointed day I wended my way to my patron's house, well primed with questions I had ready for him. He met me at once, however, with a question himself, and mine had to wait: 'Had I ever seen the new moon?' I assured him I had, and oftentimes admired the slender bright crescent, so delicate and so beautiful.

'Ah! you are wrong', he rejoined; 'we see the *new* moon rarely more than twice in a year; the moon is fully a day old, when exhibiting the thin golden crescent—but I will explain later. Meanwhile, bring paper and pencil, we must do some figuring.'

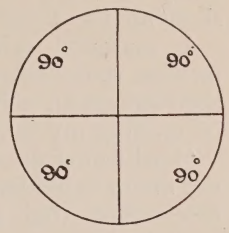
It was summer-time, and we had a table and seats on the roof, enjoying the warm fresh air, and furnishing me with his dividers and rules, he directed me to draw a circle, I being all attention.

'I do not presume that you are unacquainted with all I shall say, but our exercises will help us in our studies.

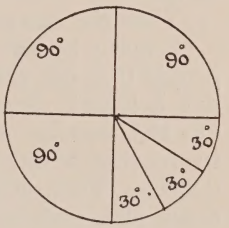


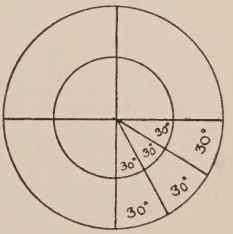
'You have your circle. Divide the circle into equal parts. How many shall we say? Well, we determine that our circle shall have 360 equal parts or divisions, and we call them degrees. Now a circle, of no matter what size, shall have 360 degrees. The larger the circle, the more extensive will the degree be, but it will remain the 360th part of a circle always. If you give your circle four divisions, there will, of

course, be 90 degrees in each quarter, as four times 90 are 360. Now draw another circle, quarter it, and sub-divide one quarter into three parts; each of these smaller parts will contain 30 degrees, as 3 times 30 is 90, or as 12 times 30 is 360. Very well, then $\frac{1}{12}$th of a circle contains 30 degrees, one $\frac{1}{24}$th of a circle equals 15 degrees, and $\frac{1}{72}$nd of a circle equals 5 degrees, and $\frac{1}{360}$th of a circle is 1 degree.



'Now draw me two circles, one inclosing the other, and let your divisions extend over both, as this: and we see at once, that while the degree remains the same proportion of a circle, the *size* of the degree depends upon the size of the circle. This method of measuring will play an important part in the science of astronomy.'





'I asked you to come this morning that you might see the *new* moon; so put down your pencil, and we will each take one of these smoked glasses. Now carefully watch the face of the sun.'

For some time we watched; at length he enquired of me what I saw.

'An eclipse! An eclipse of the sun!'

'Yes', he went on, 'I knew there would be an eclipse, and that dark body gradually making its way across the face of the sun, is the actual new moon interposing itself; its bright side to the sun and its dark unillumined side to us; we can only see the new moon during an eclipse like this.'

We watched with admiration until about three-fourths of the sun was obscured, when the eclipse gradually passed away. Turning to me, he shook my hand and with emotion said:

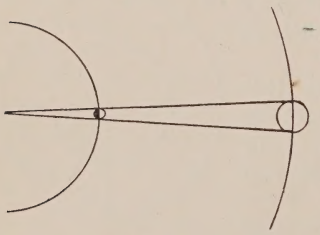
'Friend, the moon has begun to grow old, and in a day or two you will see her face partly illumined showing the familiar crescent.'

I reasoned with myself, the sun must be the farthest removed as the moon comes between—what then causes an eclipse of the moon? He seemed to be reading my thoughts, for he went on to say:

'I will now explain how it happens that at times the moon is hidden by something stealing across her face. And that something is the shadow of our earth.'

'Then the sun *must* be behind our earth?'

'Exactly! Yet this phenomenon will not satisfy people that our earth is a globe. Ah! no—they will not believe! Now let us get to our paper again. On the smaller circle—the inner one—put a spot to represent the moon; very small—less than one degree. Then draw radial lines from the centre that shall just enclose the spot standing for the moon, continuing the lines until they reach the outer circle.



In the larger space there shewn, draw another spot; this shall represent the sun. To a spectator in the centre, sun and moon appear identical in size, the actual difference being in the proportion of the two circles. Could we learn how distant they are, we could easily determine their size.'

On the morrow I left my kind preceptor, and the fair city of Alexandria, and was destined never to meet him again.

CHAPTER III

COPERNICUS PUTS US RIGHT—A RE-ACTION!

THERE was a great commotion last evening at the meeting of the Copernican Society. For some time past, the views of the eminent astronomer, our honorary president, had been discussed, but now that he had boldly asserted his conviction that we live on a planet no bigger than Venus, and that we too travel *round the sun*, there is an uproar! For my part, I pin my faith entirely to his theory, though the great and mighty, who ought to know a demonstration when they see one, will have none of it, counting his statements sheer nonsense and pernicious heresy. But onslaught upon venerated theories was ever boldest vandalism!

The system now put forward avoided many awkward dilemmas that attended the Ptolemaic. My erstwhile friend, in assuming the Earth to be fixed, conceded, nevertheless, that Mercury and Venus attended the sun as his special satellites. It was impossible for it to be otherwise; Venus the morning star and Venus the evening star, one and the same, never far distant from the sun; Mercury, too, always quite close, proclaim their near relationship to the King of Day. Now, Copernicus, by putting the earth in her right place as the third planet revolving round the central sun, introduced order and symmetry into our beloved science, and many of the old difficulties vanished at once.

Said Copernicus: 'We find in this arrangement what can be discerned in no other scheme — an admirable symmetry of the universe, an harmonious disposition of the orbits. For who can assign to the lamp of this beautiful temple a better position than the centre, whence alone it can illumine all parts at once? Here the sun, as from a kingly throne, sways the family of orbs that circle around him!'

It might be humiliating perhaps, after thinking ourselves everything, to find our world and habitation reduced to an item, but so it will prove. And it is being plainly enforced upon my mind, that if our own world is receding from paramount importance, as it would appear, the universe about us is looming larger as our knowledge increases; though our terrestrial home is thus circumscribed, our mental and spiritual faculties are given boundless scope.

Pondering thus, I reached my home after an exciting evening, and getting out my old drawings I gave myself up to study. I looked fondly on the two circles I had made illustrating an eclipse —first, the moon's circle; secondly, the sun's circle. Now I must draw another circle for the far off stars. Ah! how far indeed must they be! Could we get a clue or some base line it even might be calculated.

Thanks to the rectification of the circle, that is the proportion the circumference bears to the diameter, being now determined, we have *that* solid basis to start with. As 7 is to 22, so is the diameter to the circumference; or, as 7 is to 44, so is the *radius* to the circumference.

The apparent diameter of the moon, when at a fair altitude, could differ but little from half a degree; so that 720 moons, side by side, would fill the whole circle of her orbit. A friend of mine came in that evening, and I recounted my cogitations, remarking, 'It only remains to find the value of a degree at her distance to know her diameter; or to find her diameter to know her distance.'

We were sitting on the verandah while discussing the obstinate problem, and I dismissed the matter, as I thought, by a careless remark. I had observed that 'were yon flagstaff at the end of our garden only the moon, we soon should measure it, standing as it does right in the centre of yonder gateway.'

'It appears to me', he rejoined, 'your flagstaff-moon would stand in front of the wall at the side, and not at your gateway.'

'Eureka!' I cried, slapping him on the back.

'Now we have it! My dear fellow', I continued, 'we never shall make progress in company *here*, we must separate. You must see the moon from your standpoint, and I from mine.'

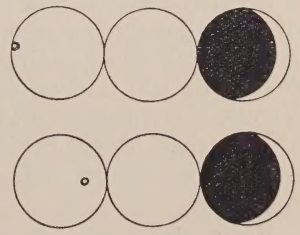
I found out afterwards, that these conditions were already known, but at the time it seemed to me an inspiration.

It chanced he had business to transact in Circassia, about 1,500 miles eastward, a month hence, and we made our arrangements thus: At a given hour soon after sunset, and when the moon was two days old and so not too bright, which would the better suit us, he was to measure carefully the distance of the nearest bright star. At the same moment I was to do likewise; and we both were to properly record the result, so as to compare when we met.

My premise was this, that he would see the moon more to the west, and I would see her more to the east, than would a third person at a place half-way between us: as he and I had viewed the flagstaff differently from either side of our table. And that difference would be the equivalent on the sky to the difference in miles between our stations.

I accordingly made my observation on the appointed night, and waited with what patience I could my friend's return.

It was many weeks before we once more met in our accustomed place, and we both were ready to compare notes.



On my paper I had figured an exact delineation of the moon — the crescent, and the dark part filled in; and adjoining this circle, two others of the apparent diameter of the moon thus:— and at the point where I have made a dot was the star *Spica* in the constellation called the *Virgin*. My friend's drawing was as I now show; the same moon and dotted circles, but his star's dot only three-quarters of a diameter different from mine! Imagine

our surprise and disappointment — three-quarters difference only; and we expected such a difference as would solve for us our problem!

However, we got pencil to paper and this is what we evolved. The moon we estimate at about half a degree—we are three-quarters out in our observations for our 1,500 miles—therefore, adding the other quarter, equal 500, we have 2,000 miles for the moon's diameter, which is as good as allowing that a degree at her distance must measure 4,000 miles. The rest seemed easy:

$$360 \times 4{,}000 \text{ is } 1{,}440{,}000,$$

which number of miles is the journey the moon performs in one circuit. The figures were far more colossal than in our haste we had dreamed of. Nearly one and a half millions! Now the diameter of this is rather less than one-third, or as 7 is to 22. But wanting the radius, we say as 7 is to 44 so is 1,440,000 to the distance of the moon from the earth. So we divided the circle of 1,440,000 by 44, which gives 32,727 and a fraction, and this we multiplied by 7, and our answer was 229,089, which showed us the moon's distance in miles.

We were pleased with ourselves beyond measure with these results. True, we had but crude data, but we were satisfied that within a small margin we must be right. We were only sorry that we were unable to judge the sun's distance as easily.

So at the distance of nearly a quarter of a million of miles our Queen of Night pursues her silent way. And we ourselves, taking the moon with us, journey round the sun and so also do the planets, Mercury, Venus, Mars, Jupiter and Saturn.

But what about the stars? Who shall tell their number, or define their wondrous paths?

* * *

Very pleasant indeed was it at our monthly meeting, to hear the demonstrations of the various problems propounded. For fourteen centuries had the erroneous views of Ptolemy held sway, with all their cumbrousness, but now, as I have said, order

was introduced, and with it charming simplicity. Circle and circular motion was the law everywhere, but here I should mention, there was a special order of motion observed by the planets, an order all their own. It was circular indeed, but circular in a double sense. A gamble—a trundle round their orbits, as it were; or as it was called an epicycle; as though the axle of an immense invisible wheel were carried around the sun, the planet itself moving on the outer edge of this invisible wheel. Of course the speed at which they went was far greater than the axle, or centre of their going, but their true motion, when understood, beautifully explained the retrograde motion they oftentimes exhibited, as it appeared from our Earth.

Mercury, the planet nearest the sun, is somewhat difficult to see, his light being overpowered by the surpassing brightness of the sun. I had observed him twice, and a beautiful sight he is. Copernicus himself — our leader — never once saw him, which was to him a keen disappointment, and to which he frequently gave expression.

* * *

I am almost ashamed to record what follows. . . The great Copernicus was dead and his system had fallen into disrepute. One, Tycho Brahe, a Dane, was paramount in his stead. It was in the sixteenth century, and he, of noble family, assisted by the King Frederick II., devoted his energies to undo all his predecessor's work.

The world again believed the earth to be fixed! The sun once more, with all his retinue of worlds, revolved around our own!

I am more ashamed still to relate that I myself was also swayed by the speciousness of the arguments put forward. 'How could Copernicus be right, when it is considered, for instance, that no sense of motion is experienced?' 'Did the earth revolve, would not stability be destroyed — more particularly at the Equator?' 'The atmosphere must whirl away, and all substances be precipitated into space!'

We failed, however, to be impressed with the

suggestion, that a far greater speed must of necessity reside in the motion of the stars! What about *their* whirling in their larger journey? Had we then known that they were at least 200,000 times farther removed than our sun, we should have been forced to give in, but such incredible distances were outside our ideas of possibilities.

He, Tycho, however, did at least one memorable thing. Besides elaborating a wonderful observatory, and furnishing the same with most notable instruments, he compiled a very exact list of 777 fixed stars, noting many particulars concerning them for the use of succeeding ages. For twenty years he devoted himself assiduously to the science at his splendid watch-tower in the island of Hoene.

A noble-hearted man, as well as high-born, he cultivated the acquaintance and greatly assisted the researches of a young astronomer named Kepler, whom he presented to the King, and who was destined to be an epoch-maker for the ages.

Tycho died in 1601, leaving his instruments and books to his companion and assistant, with the express injunction that he was not to revive the error of Copernicus.

Nature, however, will not bend herself to the hypotheses of her admirers. We may observe her facts, or we may misunderstand them; she will however reveal herself truly to careful and long-continued study, and the master mind was now ready and willing, humbly to sit at her feet.

CHAPTER IV

KEPLER PROPOUNDS HIS TWO LAWS

JOHANN KEPLER, born in 1571, near Stuttgart, was just thirty years old when his friend Tycho Brahe died, whom indeed he then succeeded as royal mathematician. He was a man who experienced a lot of domestic trouble, and was often very poorly

off; was very impressionable, and at times very odd in his behaviour. He was elated beyond measure at an idea of his as to the actual movements of the heavenly bodies, which idea was as wild as any the ancients had ever conceived, saying 'The intense pleasure I have received from the discovery never can be told in words.'

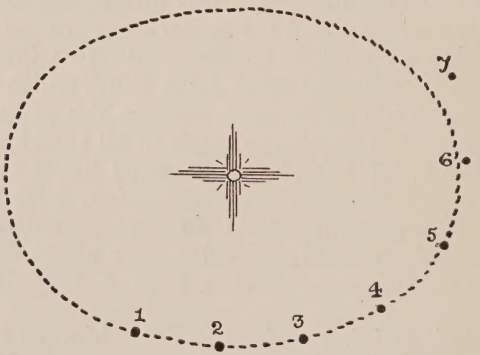
A little *imagining* suited well the spirit of the age, but presently he got hold of a definite resolve, to learn the TRUTH. Some people think that all genius is madness, and that madness is only genius run wild. Suffice it that at the time I was introduced to him, he had just demonstrated the *actual* course of nature and was ready to publish to the world two immutable laws—to be followed later by a third, which was to immortalize his name, and become the groundwork of astronomical science throughout all time!

The Age of Wonder and vague hypotheses was now to give place to acute reasoning, aided by the great advancement made in exact mathematical science. Cycles and epicycles were all to be swept away as so many cobwebs from a long-neglected room.

Kepler's training eminently fitted him for the task. Conversant with the two schools—Copernican and Ptolemaic—and with a mind satisfied with nothing less than demonstration, it was not long before he was forced to relinquish the idea that nothing could be uncertain in the order of nature, but that what appeared uncertain, was only seemingly so from our standpoint, and it follows that if Copernicus was right—the sun being the centre of our system—the observer, to get a right notion, must transport himself in all but actuality to the sun's centre and from that standpoint read and understand all planetary motion.

I now proceed to relate in order Kepler's great discoveries, bearing in mind his main thought, that nothing could be of chance, but everything absolutely in order in the universe. If a circle, then he must know it to be round, and trace its roundness; and to this end he carefully followed the course of the

planets one by one, and it was here that theory and observation disagreed. The planets refused to come up to time, as properly disposed circle-going planets should have done. Was nature wrong, or was Kepler wrong in what he expected of nature? Why, Kepler must be wrong, so he set to work again. There were other forms than circles, so he contrived an imaginary course of an oval shape, and, as he expressed it, would hunt down one thought after another until he caught the one in which theory and observation agreed. In watching thus you will

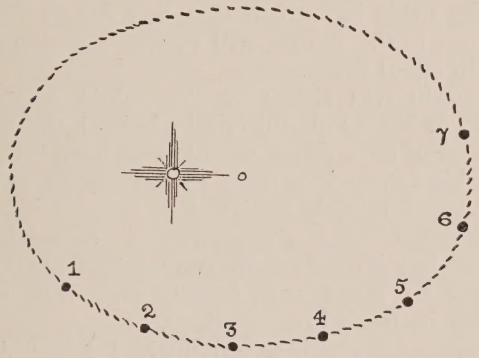


remember he supposed himself to be central with the sun, and patiently he noted how the planet departed from the circle—quite right—and followed the oval—again right—but just as he waited for the performance of the second half of his oval, the planet continued his onward march, leaving my friend once more in the lurch.

Here is the state of the case: Kepler was tracing the planet from positions one to six in glad satisfaction for more than a year, when lo! a few weeks later, the runaway planet was discovered at point seven, right off the prescribed track!

This was a severe blow to him, still he was in search of what he was confident must be a properly constituted path, so he applied himself again to the task, and none but he and his immediate friends knew of the travail of his mind the while.

One day I was closeted with him in his study—the table was strewn with papers, plans and sketches, and many calculations I was unable to follow, when he again drew his oval thus: driving two pins a little



apart in the middle of a sheet of paper; then making a loop of string, he was able to make his oval by putting the loop over the two pins, and his pencil in the other end of the loop, much as a gardener would do in describing a flower bed.

'What if I suppose the sun, instead of being central, to be where my pin is?' he exclaimed.

We could only suggest that he should try.

With painstaking care, the planet (Mars) was watched through the long weary months. With obedient precision did the planet perform his journey, but before its actual completion he knew that the goal was won.

The circle was *wrong*, the oval was *wrong*, but Eureka! the ellipse was *right!*

With commendable thoroughness he watched the paths of the other planets. They observed the same law. He was then prepared to announce to the world his great discovery, excepting for one point, namely, although the paths were clearly traced, the speed at which the planets travelled, was not at all times uniform.

More thought; more watchings; more hypotheses

—then the triumphant outcome. He had discovered the two prime *laws of planetary motion!*

(1) Every planet revolves in an elliptical orbit about the sun which occupies one of the foci.

(2) The velocity of the planet on every point of its orbit is such, that a line drawn from the sun to the planet, will sweep over equal areas in equal times.

The world was richer by the subtle determinate workings of his wonderful mind; indeed, the brilliant discoveries of later times would have been impossible had not his conclusions been so laboriously struggled for, and so completely achieved.

I regretted that circumstances compelled my departure, but important matters called me to Italy, so I had to leave my friend, who was already immersed in fresh investigations.

'For what are you now striving?' I asked him.

As he shook hands with me, he replied 'I can hardly tell you, yet it seems to me there must be other points of resemblance between the various members of our family of planets, and it is my business to find them out.'

On the morrow I was on my way to the City of Florence, where, needless to say, the fame of Johann Kepler had preceded me.

CHAPTER V

GALILEO AND HIS MAGIC TUBE; AN ALTERCATION AND A TRIAL. THE LAWS OF MOTION

A FEW months after my arrival I received a letter from Kepler, and an epistle enclosed therein for personal delivery to Galileo Galilei, which thing was to me the most fortunate that could have come about. I had longed for a look through his wonderful telescope, and here was an interview with the notable philosopher thrust upon me. Moreover, there was a request in the letter that a copy of

Galileo's work entitled *Siderus Nuncius* should be given me.

How vast the importance of the magic tube to the furtherance of the science, time only would show. It came about in this wise. An optician, named Jansen, of the city of Middleburg, about the year 1609, found out that by placing two glasses at some distance from each other, suitable to their respective focal powers, distant objects were apparently brought quite close, and also magnified them. Although he was not the first that did this—indeed, it is said that some children playing with glasses accidently discovered the same thing—nevertheless, he, Jansen, first finished a workable telescope, and with some state presented one to Maurice, the reigning prince of Nassau.

Not much use was made of it until the alert mind of Galileo seized upon the idea for the purposes of astronomy. The principle of the contrivance I may here shortly explain: A convex glass, say of 18 inches focal distance, is placed at one end of a tube, and the light of a distant object falling upon it is refracted, as it is called, and in passing through, the rays of light converge to a focus where a perfect image is formed. A convex glass at the near end with a focal distance of, say, 2 inches, is so placed that it will bear upon the small image, formed by the larger one, and magnify it in the proportion of their focal powers, that is to say, in the case supposed as 2 is to 18. In other words, it will have the effect of bringing distant objects nine times nearer than seen by the unaided eye.

This was about the power of Galileo's first telescope, I understand, but as he told me, he spared neither labour nor expense, but made an instrument so excellent as to show things thirty-two times nearer than the eye beheld them.

Before my arrival he had put his tube to good purpose. He discovered that our resplendent sun was marked by many dark spots that traversed his disc, and this proved that the sun also revolved round himself as does our earth, and the time of his rotation was found to be about 600 hours, or 26 of our

days. The familiar marks on the moon became mountains and huge craters. He viewed Venus and beheld a crescent, or miniature moon, and in Jupiter! what a sight ravished his eyes here! The lovely planet magnified into a moon, had no less than four satellites attending him, revolving quickly, sometimes on one side only, sometimes one on one side and some on the other. What a communication to make! In Saturn was a new surprise. A body of unusual shape, having *appendages*, that, although not altogether discernible, were dissimilar to all else he saw, and that made him long for greater powers. He gazed at the seven stars of the Pleiades and lo! seven times seven leapt into view, and in the blank spaces of the heavens where the keenest eye detected nothing, dozens of stars appeared in response to the searchings of his wondrous glass. That this made a great to do, you may suppose, indeed, a violent opposition to the bold astronomer was soon organized.

One philosopher (*sic*) declared he would not look through his glass lest he should see the pestilent worlds! Referring to Jupiter's moons.

How Galileo laughed when telling me of this, but he only replied, at the time, 'He hoped the objector would see them at his death on his way to heaven.'

It appeared Kepler wanted Galileo to pay him a visit at the earliest opportunity, that being the burden of the letter that had arrived, and some months later I journeyed with Galileo, my business in that part being completed.

It was about this time he told me of the laws of motion he had published after long study, and how he had publicly demonstrated their correctness when residing at Pisa in the capacity of teacher of Philosophy.

'Aristotle', said he, 'had in the opinion of most people, said everything that was worth saying—and many remarkable truths were capably shown by the ancient Greek; and, indeed, his formulas, axioms and doctrines were accepted as laws, against which it were heresy to object. Yet, after my conversion

to Copernicanism', he continued, 'I began to study the properties of matter and motion, and to teach the conclusions I arrived at to the various classes. It was thus I fell counter to the teachings of Aristotle —How dare I!'

'What was the outcome of the unpleasant contention?' I asked.

'Why, this', he explained: 'I must either desist, or vacate my chair. I first proposed a test, arguing it was only fair I should be proved to be wrong. I did not expect it, but they graciously consented.'

'First, please tell me distinctly the point at issue', I requested.

'For instance', he rejoined, 'all teachers from Aristotle downwards have taught that a weight of, say, 1lb. will fall from a height, in the same time as another weight of 1lb. Very good; then it is stated that a weight of 2lbs. will fall twice as quickly — a weight of 1lb. 8ozs. one and a half times as quickly, and so forth.'

'Well, I should have thought them right', I interrupted.

'Of course', he resumed; 'and so all Aristotelians thought, but it was just there I joined issue with them. I taught that two weights of *unequal* masses let fall from a height would descend both together in the same time. The thing appeared an absurdity, and so my proposal for a test was accepted. The trial was to be from the top of the leaning tower, which was the very thing for it. I was to be at the top and a few of my friends were watching below. Some of my opponents were with me, and a big crowd waited for the fall — of the weights actually, and of myself metaphorically. After due precautions were taken that no witchcraft might interfere, and after a careful weighing of each ball, the signal was given and I let them go. A few seconds, and they struck the ground together. Yet must they be quite sure, so the ceremony is enacted a second time—and then the third time. The result was always alike, and I am glad to relate the enthusiasm of the moment carried all before it. I

was acclaimed victorious. Yet in that hour I made many enemies.'

'It is marvellous', I remarked, 'how prejudice will blind people, otherwise sane enough, to the evidence of their senses.'

'It is', he replied; 'and I have thought that had not Elijah taken the precaution to direct the slaying of the priests of Baal at his testing time, the enthusiasm his triumph evoked would have been short-lived.'

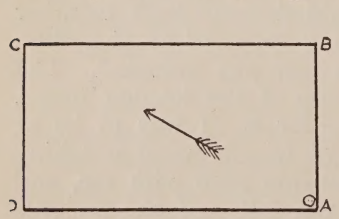
* * *

'Will you explain what you consider the laws of motion?'

'First: A body moving, does so in obedience to an impulse received, acting in the direction of its motion—or else, the direction of the movement is the resultant of two or more forces (impulses), of which the direction is the mean.'

'By which I understand, that if one force impels in a straight line, and at the same time another force acts at right angles with the first, the body acted upon will move neither in the first direction, nor the second, but between the two.'

'That is so, and may be made clear by this drawing: You will recognize that as a parallelogram, and see, I place at one corner a football, and name the respective corners, A, B, C and D. A player kicking the ball at A towards B, will of course impel it simply in that direction, or should he kick it towards D, in the direction of D would it travel, but suppose two players kick the ball at the same time, one towards B and the other towards D, then neither B nor D would receive the ball, but it would be precipitated along the diagonal ending at C in exactly the same time as the result of the two forces as it would have landed at D as the result of one force. This we call the parallelogram of forces;



and the quantity and direction of the diagonal is equal to the quantity and direction of the two sides.'

'What if two forces exactly opposite were imparted?'

'Then if the two forces were equal there would be no motion; if unequal, the motion generated would be that produced by the more powerful, minus, *exactly* the amount of the weaker one.'

'You showed at Pisa, that unequal weights descended in equal times, how is that consistent with the effect of different forces being different in precise ratio? Are not the weights powers, or forces?'

'No, I judge not, in the view we are now taking of them. The weights were falling, but there was but one power, and that residing somehow in the one Earth, acting on both alike.'

'Ah! But tell me, suppose a mass of lead and a mass of cork—would they both descend together?'

'They would I am convinced, were they equally protected from any extraneous force. Cork, however, would not withstand in the same measure as the lead, the effect of a strong wind, for example, which would have to be considered as a force.'

'Do you think the study of these facts will be of material service?'

'I have no doubt our friend Kepler, to whom we are going, will say they are. I have already sent him my

Two Rules of Motion:

(1) *That every body will continue in its state of rest, or of uniform motion, until it is compelled by some force, to change its state.*

(2) *That the change of Motion is proportional to the force impressed, and in the direction of that force.*'

I could not but think how simple the two laws appeared to be when thus defined, and I was about to make that remark when a new thought struck me.

'How', said I, giving voice to my idea, 'how is it that mere inert matter, whether large or small, must

remain resting or continue going necessarily? Or perhaps, I should ask, what principle is it that so compels?'

'Because', replied Galileo, 'inert matter *is* inert, and the essential attribute in-dwelling we call *inertia* —there is in matter no power to alter either state, and any alteration attending must come from without.'

'Permit another question', I continued. 'Suppose a strange world—outside the family of planets—poised in space—where would it fall to?'

'Poised in space is your assumed condition', he replied, 'that means that your imaginary world is without the reach or control of any force, and owns allegiance to no central sun; such a globe would remain "poised" and stationary, and would fall nowhere. Whence indeed could it fall? For which way is "down" or which "up"? Which way is "right" or which "left" in illimitable space?'

The thought somewhat oppressed me, and I was glad to recollect that, apparently, at any rate, motion, indicating progression, was the order of the spheres.

At length, our journey done, we came to the city of Prague, where Kepler awaited us.

CHAPTER VI

MEETING OF GALILEO AND KEPLER. THE THIRD LAW OF PLANETARY MOTION

I CANNOT dwell long on our meeting—the two philosophers and myself. It was a glad one, for we had kindred interests, and much to compare, but there was depression in it as well as gladness. With all his triumphant record Galileo was looking forward to trouble in Italy; and Kepler, notwithstanding he was on the verge of a grand discovery, yet was he struggling with poverty, domestic trouble, and with an inappreciative public. The acquisition of knowledge may be its own reward, and even so, the consciousness

that one is doing that that must benefit posterity is often enough to sustain noble souls.

Kepler informed us his present purpose was to establish, if possible, his suggested relationship of the several planets, as obeying some law, in their times and distances.

Said he to Galileo: 'Your laws of motion will certainly help me.'

Continuing, he explained how he had squared their distances, and squared their times, or periods, and had tried other ideas, but had not yet reached any goal.

When in lighter vein we chatted of our opponents. We indulged in much merriment when, for example, Galileo told of the 'Philosopher' of Padua, who would not look through his telescope; of Martin Horley, who said he never would concede his four new planets —meaning Jupiter's moons—'to that Italian', though he should die for it; and of Sizzi, an astronomer of no small reputation, who essayed to show why only seven planets could exist in the propriety of things.

'There are', said this redoubtable logician, 'seven windows given to animals in the domicile of the head, through which the air is admitted to the tabernacle of the body, to enlighten, to warm, and to nourish it; which windows are the principal parts of the microcosm, or little world—two nostrils, two eyes, two ears, and one mouth. So in the heavens, as in microcosm, or great world, there are two favourable stars, Jupiter and Venus; two unpropitious, Mars and Saturn; two luminaries, the Sun and Moon; and Mercury alone, undecided and indifferent. From which, and from many other phenomena of Nature, such as the seven metals, etc., which it were tedious to mention, we gather that the number of planets is necessarily seven. Moreover, the satellites are invisible to the naked eye, and therefore can exercise no influence over the earth, and therefore would be useless, and therefore do not exist. Besides, as well, the Jews and other ancient nations, as modern Europeans, have adopted the division of the week into seven days, and have named them from the

seven planets. Now, if we increase the number of Planets, this whole system falls to the ground.'

Such was the inexact science prevalent at the time; and as Galileo put it, arguing as if with magical incantations to '"charm" the new planets out of the sky'.

Many matters beyond the range of my limited understanding were discussed by the two scientists, and the hour of parting came; Galileo to return to Florence, and we two to our several concerns.

* * *

With exhaustless patience Kepler worked at his calculations, finally evolving the crowning masterpiece:

THE THIRD LAW OF PLANETARY MOTION:

'The *squares* of the periodic times, are proportional to the *cubes* of the *mean* distances.'

In plain words, what Kepler discovered was that *all* the planets obeyed one law as to velocity, depending absolutely on their relative distances. The Earth performed her orbit in $365\frac{1}{4}$ days: multiply $365\frac{1}{4}$ by $365\frac{1}{4}$, that is square the period. Mars completes his orbit in 687, multiply that by 687, and so on with all the planets. Now *cube* the distances. Take the Earth's distance as 91,000,000 miles: multiply 91 by 91 by 91. Take Mars' distance as 142,000,000 miles: multiply 142 by 142 by 142, and so on with all the planets.

As the *square* of 365 is to 687, so is the *cube* of 91 to 142.

Or as 365^2 is to 687^2
So is 91^3 to 142^3.

Mercury, Venus, Jupiter and Saturn, all fell in with Kepler's arithmetical chart, as obediently as did Mars and Earth.

Such was his work!

FIRST LAW.—The shape of the orbit with the sun out of the centre.

SECOND LAW.—The speed of the planet at different parts of its orbit.

THIRD LAW.—The Commonwealth or Brotherhood of the planets in the performance of their motions.

For nineteen long years he toiled at his figures.

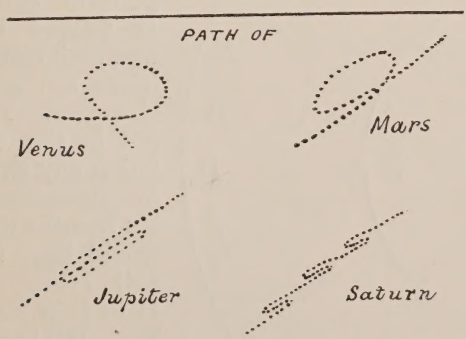
For nineteen years with wearisome vigil he traced the planets in their courses; but while nineteen centuries wend their way will his fame endure, as the Philosopher Astronomer, who laid the ground-work for *all* subsequent discovery!

Kepler was exultant. His final rhapsody is excusable.

'Nothing holds me!' quoth he; 'I will indulge in my sacred fury; I will triumph over mankind, by the honest confession that I have stolen the golden vases of the Egyptians to build up a tabernacle for my God far from the confines of Egypt. If you forgive me I rejoice; if you are angry I can bear it; the die is cast, the book is written, to be read now or by posterity, I care not which. I may well wait a century for a reader, as God has waited six thousand years for an observer!' And then devoutly: 'I give Thee thanks, Lord and Creator, that Thou hast given me joy through Thy creation; for I have been ravished with the work of Thy hands.'

* * *

One day I enquired of him how it was that the



planets did not pursue a regular course, but described orbits as in the preceding figures. He soon made the matter clear to my understanding. 'The planets pursued a track that was very regular—the *retro-*

gression being only apparent. The *epicycle* was invented to explain the seemingly irregular path—it was the clever explanation of uninformed minds.'

'Yet', said I, 'I myself have noted Mars travelling east, then west, and finally east again, with respect to the surrounding stars. I can be positive of that.'

'Did you commit your observations to paper?' he enquired.

'Yes, I can show you in this notebook exactly where the planet appeared.'

'Just so', he responded. 'Let me commend your habit of making notes—it is most important; yet, nevertheless, the irregularity is only apparent.'

Then taking paper and pencil, he bade me draw two circles, one within the other.

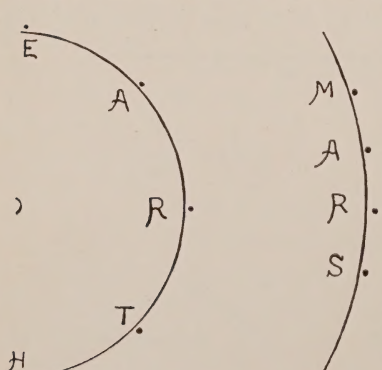
How my ears burned! Did not Ptolemy teach me the eclipses by *two circles?*

Then he directed me to mark the inner circle EARTH and the outer circle MARS.

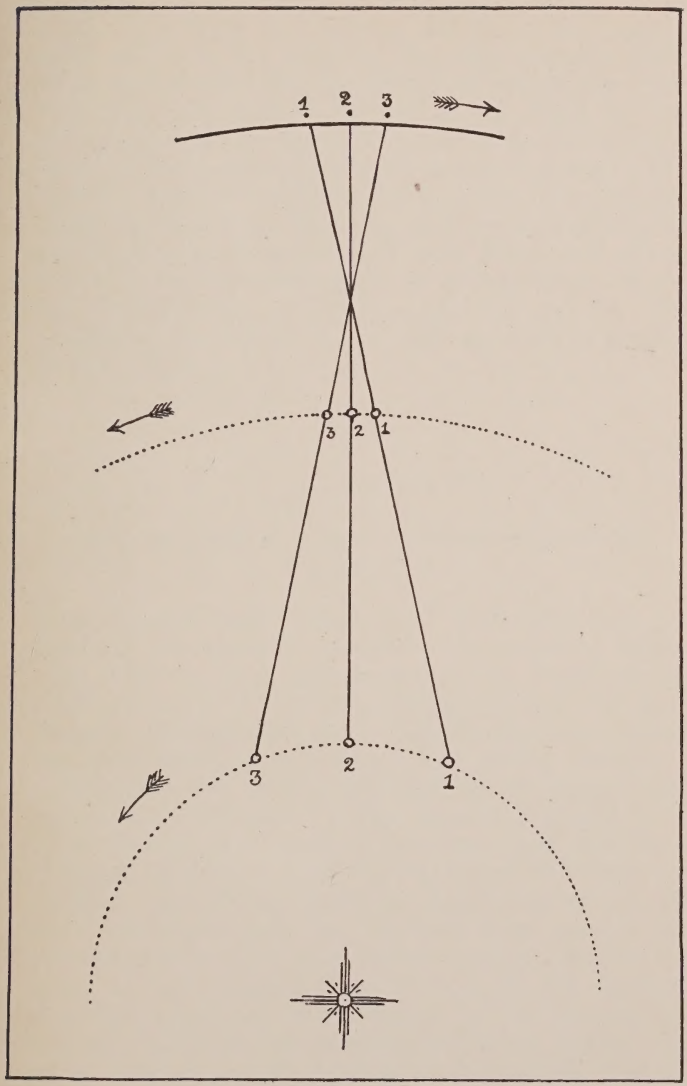
I made the figure as in the margin.

'Now watch closely', said he, 'and you will observe that while both orbits shall be regular, the appearance shall be far different.

'The Earth travels round once in 365 days; Mars takes 687 days to perform one circuit. It follows therefore that their relative positions are constantly changing. They are not in the same relation any two nights in succession. In six months the Earth would have travelled half round or from H to E in your drawing. But in the same time — 182½ days— Mars would have only described $\frac{182}{687}$ of his journey, that is to say, not much more than one-fourth.'



I then, at his direction, drew some lines on my


1
2
3
3
2
1
3
2
1

drawing which thereupon looked as shewn. The lines start from the several points in the earth's orbit and pass the point in the outer planet's orbit, allowing for the different speeds at which they are travelling. Then, by continuing the lines to the background of the heavens, it was apparent that the forward line intersected and passed *behind* the earlier line. I could then understand how the other planets, Jupiter and Saturn, also appeared to retrograde for the same reason, stand still, and afterwards shoot forward with increased speed—a phenomenon caused by the different positions occupied by us, the observers, by reason of the various relative speeds in the orbits.

CHAPTER VII

REMINISCENCES. THE DISCOVERY OF THE BAROMETER

SOME years had passed, and Torricelli, one of Galileo's most ardent disciples, was spending some time with me, and our thoughts and conversations were upon the trials and vicissitudes of our late friends. Galileo had died; Kepler also was dead, but their work, undoubtedly great, would remain.

Torricelli was deeply moved, when reciting to me events that were none too well known to myself.

'It was in a Cathedral at Pisa that Galileo's thoughts first turned to the study of the laws of motion. The great chandelier had by some means been disturbed, and he watched how steadily it swayed from side to side, before coming to a stand-still. It was investigated by him in his usually thorough way, and the principle of the pendulum was the outcome, the curious conclusion arrived at being, that a pendulum of a certain length always oscillated or vibrated in the same exact time. For instance, one 39 inches long would occupy one second each way—whether heavy or light, making

no difference. That being so, one might think that a pendulum half as long only, would beat half seconds: but no, a pendulum a quarter of the length of the first beat the half second. Further, he found that whether the arc described, be a large one or a small one, did not affect the period; if a large one, it moved the quicker; if a small one, then slower, so that the entire sway was performed in the exact time belonging to the length. 'Here', said he, 'was a simple, but marvellous discovery! What a measure of time! Given a pendulum, and you have your time.'

'Oh, friend!' said he to me, 'what a world is ours, that the lights and geniuses that arise, are so ill used, and hardly understood.'

And he told me of the persecution Galileo suffered at the hands of the Inquisition. How he was hailed before the tribunal and made to subscribe things against reason and his conscience, and even then committed to prison. On his knees he was made to say that the earth was immovable, and that the contrary was absurd, philosophically false, and theologically considered, equally erroneous in faith.

Grasping my hand, Torricelli said, with tears in his eyes, 'Our friend had not said that, but for the horrible tortures to which they subjected him—the Most Holy Inquisitors, breaking his body upon the rack—yet at times, even so, the tone of his voice, and the ironical phrases he used seemed to suggest "Reverse all I say", and, indeed, when the ordeal was over, he turned to me and a few others near by, saying in a low tone, "IT MOVES FOR ALL THAT!"'

'Our poor dear friend has gone', he resumed; 'but yet he had his hours of public triumph. You remember the scene at Pisa for one. On another occasion I went with him at special invitation of the Senators of Venice to demonstrate before them the powers of his telescope—you know the clearness of the sky there—everything was favourable on the night selected; the moon was but two days old, Venus was shining brightly, and Jupiter was high up in the heavens, with three of his moons visible.

It was on the top of St Mark's that Galileo mounted his instrument, and as one senator after another freely and honestly inspected the objects towards which Galileo directed his glass, they were at once convinced and delighted. At the conclusion they invited him to lecture, on the concordance of their own eyesight, and the Copernican theory, which he did most clearly.

'In Jupiter they saw a system in miniature; in Venus they saw a reduced copy of our moon; and they straightway acknowledged their conversion to the new philosophy.

'Although in the end, the Holy Inquisition crushed him, posterity will give him his due.'

I mused within myself, how small was I compared with the giants I had conversed with, yet I comforted myself a little with the thought, that although the communication of great truths was pre-eminently good, yet the acquisition of knowledge was good also, and I was glad to be a sharer in that.

Before parting with my friend I asked him what he was applying himself to. He replied:

'I am in truth now on my way to see Pascal, who has perfected an instrument I recently constructed, which he says will measure the weight or pressure of the air in any given place, and you will be interested in this, for Galileo himself was the one who led me to experiment.'

'I shall indeed be interested', I put in; 'but how measure the pressure of the air? Is that pressure variable?'

'Undoubtedly. We have only to remember that cold air is lighter than hot, and that currents of hot air from the equator and cold air from the poles are for ever interchanging position, and in a storm striving for the mastery. As a consequence, the weight of the atmosphere is as variable, as at the particular time there may be a denser warm or a rarer cold current. It is stated that the instrument may even be used to foretell pending changes and so be of material use, commercially.

'But to my tale. You have heard of the suction

pump, perhaps you have used one to raise water. Well, our Duke wanted a pump for use in his park that would raise water for the space of nearly 50 feet—he could not procure one. Galileo essayed to accomplish the task, but try as he would, no water could be induced to ascend more than about 32 feet. Now Galileo put the blame, so to speak, upon the atmosphere. And rightly so; indeed, it was the atmosphere that controlled the whole action and not the matter of suction at all.

'It occurred to me at a later date that I might prove this by an experiment. For since mercury is about thirteen times heavier than water, a column of mercury equivalent to 32 feet of water would be a thirteenth of this in length, or about $2\frac{1}{2}$ feet. If then I take a tube about 40 inches long, and sealed at one end, then, filling it to the brim with mercury, close the opening with my finger and bring it under the surface of mercury in a basin, upon taking away my finger, the mercury column ought to fall until it measures $2\frac{1}{2}$ feet long from its top to the surface of the mercury in the basin.

'I am told Pascal has taken, or caused to be taken, such an instrument up a mountain side with the result that a very different height of the column results. If so, it will demonstrate my idea as an air meter of delicate and real utility.'

I asked him did he think the invention of use in Astronomy. He rejoined:

'There is a kinship in all Science. And, doubtless, the different currents in the air is primarily due to the rotation of the earth, together with the inclination of the poles, and in consequence of those phenomena, the ever-changing intensities of Solar heat, as to districts, and of night and day for all the world. The truths of one science will mostly corroborate the conclusions of another science. At any rate, one truth can never falsify another truth.'

CHAPTER VIII

NEWTON DISCOVERS THE LAW OF UNIVERSAL GRAVITATION: THE MAINSPRING OF THE UNIVERSE

ISAAC NEWTON, M.P.—a very giant among men. Let me record a few incidents of his life. He was born in Lincolnshire on Christmas Day, 1642—the same year in which Galileo died. When 27 years of age he was appointed Professor of Mathematics at Trinity College, Cambridge, and by that University sent to Parliament. He was made Warden, then Master of the Mint, and was President of the Royal Society. He was made Sir Isaac by Queen Anne, but what interested me most, he compacted the science of Astronomy by his discovery of the law of universal gravitation—a more lasting memorial of him by far, than the splendid monument that was erected over his tomb in Westminster Abbey, where he at length was laid to rest by his appreciative and respectful country.

He was 45 years of age, and his principal work successfully accomplished, when it was my unbounded pleasure to be much in his company.

He told me of the careful way in which he noted little circumstances, making up his vast knowledge, as a child might gather together pebbles—little by little.

He always wanted to *know*, and to know *why*. It was not sufficient to him merely to observe things to be—he must enquire why *things were*. And whilst he honoured Kepler for his three laws of planetary motion, and Galileo for his discoveries, he must needs probe deeper, to find the mechanical necessity of it all. And well indeed for the world that he did.

Let me first of all announce in large letters Newton's law of Gravitation:

> **'Every particle of matter in the universe attracts every other particle of matter, with a force or power directly proportioned to the quantity of matter in each, and decreasing as the squares of the distances which separate the particles increase.'**

The above statement of fact becomes henceforward the very groundwork of the Science.

The following is what I understood Sir Isaac to say:

'Kepler found out, entirely by observation, that the planets pursued orbits in times that were proportional to their distances.'

(Newton showed that that was necessarily so, as the result of gravitation.)

'Kepler found, solely by close observation, that equal areas were swept over in equal times, so that when the planet was nearest the sun, a larger part of the orbit would be traversed, otherwise the area would not be equal.'

(Newton showed that gravitation compelled the quicker movement, and the equal area swept over, was the natural consequence.)

'Kepler found that the planets moved in an ellipse, the Sun being in one foci.'

(Newton demonstrated that the mechanical necessity arose consequent upon the law of gravitation.)

In point of fact, Kepler was the observer, Newton was the mathematical reasoner. Again, Galileo found that a body at rest, would remain at rest; also that a body in motion would continue in motion—moving at the same rate, neither lessening nor augmenting whilst free from hindrance, or the application of further force.

The fact which next impressed itself on Newton's mind was the law of falling bodies. A body falling will not maintain the initial rate of speed only; the speed will continually be accelerating. Was this a contradiction of the second law of motion?

It was ascertained that a body falling would pass through about 16 feet in one second, yet in two seconds that same body would pass through 64 feet. That is to say: $16 \times 2 \times 2$; and in three seconds $16 \times 3 \times 3 = 144$ feet, and so on, always squaring the number of seconds.

It would therefore require less than four seconds for a body to reach the ground if let fall from the top of the monument subsequently erected near London Bridge.

Now, all this was found by observation. It was suggested, however, by both Kepler and Galileo, that the earth must be *pulling* the falling body—that that must be the why and the wherefore.

Therefore, if the earth be pulling, it is evident it will pull on the top of a pull, and if a certain velocity be given a quiescent thing, the next pull will be to a *moving* thing and the speed will consequently be greater. Here, therefore, is conformity to the second law of motion. If the earth be pulling, the pulling earth must be reckoned with. For if the earth pull, and the next second there be no earth—then the velocity imparted would continue for ever, without acceleration.

This was the particular matter Newton set himself to establish.

The law, since such a law existed, must be very exact, and the question arose, if a body falls 16 feet in a second of time at the surface of the earth, would the law hold good at say 100 miles, or 1,000 miles distance from its surface? Here was a problem, but how to get the answer.

The initial speed would be much less—probably as the inverse ratio of the square of the distance.

Surmises, however, would not do, Newton wanted to KNOW. But here he was clearly at a disadvantage. Kepler and Galileo could *observe* for their pronouncements, but Newton could not ascend 100 miles, much less 1,000 miles. Remembering Galileo's rule as to compound forces, and the medium path pursued between two or more forces, by a body thus acted upon, it occurred to him that the *Moon* was evidently

under the influence and control of two forces: for it was neither travelling straight—that is tangent to the earth, nor was it falling to the earth. *Yet, perhaps it was falling to the earth.* The initial forces impelling in a straight line, combining with a constant pulling of the earth, resulting in her elliptical curve!

If by calculation, the amount the moon *ought* to fall in obedience to gravity agreed with the *observed* fall, the significant result would be, that gravity, so evident in its operation on the earth, was also in operation at so great a distance as the moon.

To say I was interested in all the foregoing is hardly necessary. I was even prompted to interrupt with a few questions, yet somewhat tentatively, in the form of suggestions.

Of course, it was necessary to know what power to allow to gravitation at that distance; it would also be necessary to know the relative masses, to know the distance apart of the two bodies.

Sir Isaac expressed his pleasure, that I appeared to follow intelligently his exposition, and at once agreed that the points I had mentioned were quite essential to the required solution.

He continued: 'My hypothesis was this, that the attraction of the earth would lessen as the inverse ratio of the square of the distance.

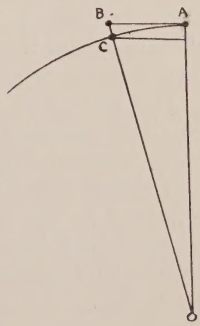
'The second and third powers, that is the square and the cube, had already appeared as factors in Kepler's investigations, and I was convinced the same properties would obtain in the matter of attraction, although as I remarked in the inverse ratio. And as in Kepler's case many years elapsed before demonstration was possible, so in mine. For many years I applied myself to the task in confident hope, yet only to be baulked in my results. I could not arrive at a uniform conclusion in conformity with my hypothesis. I gave it up, and laid the matter aside.

'Galileo had shewn that bodies fell 16 feet in one second on the earth, and as the moon is 60 semi-diameters of the earth distant, I calculated the rate at which she should fall in conformity with the

inverse ratio of the square. I found myself out of my reckoning by a sixth part, which was of course fatal.'

'And yet you have demonstrated that there is an agreement?'

'I have, but I was unable to do so until the actual —that is the correct diameter of the earth had been ascertained. And now, observe how dependent we all are one upon another. We thought the earth accurately measured, until at length doubts arose, and the King of France, backed by his ministers, determined the question should be settled if possible, and M. Picard was furnished with means and directed to carry out the work. You will learn later how this was successfully accomplished, suffice it to say, that the exact diameter of our globe was announced to be 7,918 miles. We therefore say the radius, or semi-diameter is 3,959 miles. Knowing how many times the radius, the moon is distant from us, we easily arrive at 238,800 miles as the mean distance of our satellite, and the whole circumference of her orbit, namely 1,500,450 miles. Knowing also her periodic time, we know how much is her movement in one second: namely 0.6356 of a mile.' Referring me to the drawing in the margin, he continued — 'In one second, the moon travelling in a straight line, in accordance with the first law of motion would start from A and arrive at B. We find her, however, at C. This we expect as we know her to be moving in an orbit around our Earth. Nevertheless, the difference between B and C represents the amount of *fall* sustained by reason of the drawing power exerted by the Earth, in antagonism to the original inclination to travel straight or at a tangent to the orbit.'



'What is that fall?' I enquired.

'The small one of 0.0536 of an inch in one second!'

'Did that result agree with your hypothesis as to universal gravitation?'

'Yes. At the Earth's surface gravity draws a body distant $16\frac{1}{12}$ feet, to herself, in one second. But by the inverse ratio of the force—supposing the body to be twice as distant, viz., $32\frac{1}{3}$ feet, then the first half of the distance would require not one second as at the surface but four—and if the body was thrice as far, that is $48\frac{1}{3}$, then the first third of the distance would occupy nine seconds; and the calculation extended to the distance at which the moon is gives the answer 0.0536 of an inch in one second, which is the observed fall.'

The ultimate simplicity of this complex problem interested me greatly, and I asked Sir Isaac to explain the bearings it had on the science. He showed me simply that the one force that gives weight to bodies on the earth is the same force that draws bodies to the earth, and that that force exerts a proportional influence at the moon's distance, and, said he, why not farther?

Newton's next step was to prove, as he did most successfully, that gravitation was the mainspring as it were of creation, for the same law governed the planets in respect to the Sun, that one planet affected another planet in direct proportion of mass and distance, and that Jupiter's moons also were obedient to the same law.

His work was done! Conjecture had to give place to demonstration; the why and the wherefore had been wrested from the secret heart of Nature!

Taking my leave of the great mathematician I repaired to my chambers in the City of Cambridge, where I had been residing, and thence shortly afterwards to London, then but newly rebuilt after the great fire.

CHAPTER IX

PROFESSOR HALLEY PROPOSES A PLAN TO MEASURE OUR DISTANCE FROM THE SUN

SPENDING much of my time with Dr Halley, to whom I was introduced by Newton, my devotion to astronomical study deepened. He was very patient with my slow comprehension. Yet will I say for myself, I never forgot what once I had learned.

I ventured the remark that surely finality was nearly reached, and that such as he, for instance, knew most all that was to be known. I was surprised to hear his answer, that so far from that, we were only on the threshold of knowledge.

'First, we do not know the distance of the sun accurately, this we must know.'

'Why is that so important?'

'Because it will then become our standard measure for other distances. Until Newton knew the actual diameter of the earth, he could not determine the moon's distance. The radius of the earth was his base line. Similarly, the distance from the earth to the sun will become our base line for larger measurements — hence its importance. You could not measure a length of cloth, until you first had your standard foot or standard yard. A roll of cloth would be sadly measured if your yard measure were but one inch short or long—rather than exact.

'Secondly, we know very little of *comets*. We have observed many as visitants from afar but as yet they have only puzzled the wise, and frightened the unlearned. We are beginning to learn that a large number are periodical — they come and go and come again after certain wanderings in outer space. They are evidently controlled by the sun

and are subject to the law of gravitation; but even here we are puzzled by an apparent anomaly, for while hasting toward perihelion, or nearest approach to the sun, they carry their tails behind them, but during their actual passage round the sun, the tail overtakes the head of the comet, so that in any and every position the tail is *away* from the sun, in fact when receding from the sun the tail goes first. This is very wonderful; we cannot understand the reason, or easily conceive how so contrary an effect is produced, except it be by some *repulsive* force that we, at present, are totally unacquainted with.

'In ancient times the appearance of a comet caused great consternation, as they were deemed portents of evil; while others feared a possible collision with one, lest universal destruction should follow. Now, however, we know that their substance is of a most attenuated nature, and fear of any danger has long passed in civilized countries.'

'One, I understand, is called by your name, Doctor', I remarked.

'True', he said, 'I have been somewhat successful in noting that a certain comet had been seen at intervals of about 75 years—that the axis of its orbit could be no less than 3,400,000,000 miles, and I have announced with confidence that it will once more return in about the year 1759.[1] Before then, other comets will be as closely studied and other men's names associated with them.

'The calculations are comparatively simple, but what shall we say of the power and wisdom of the Great Creator of all these sources of wonder?

'Reverting to my first point—the sun's distance from the earth. The parallax of the sun is so small that it is very difficult accurately to measure it, for our base line of 4,000 miles nearly (the radius of the earth), is much too short for the purpose.'

'I would be glad to know more about parallax', I remarked; and he informed me that the word was derived from the Greek: *para* beyond, and

[1] It did so return, also in 1835, and is due once more in 1909.

4
4
4
8
4
12
4
16
Semi-
Diameter
4000
MILES.
EARTH.
4000 X 60 = 240,000 MILES.
MOON.

allasso, I change. That diurnal parallax for the sun and planets and the bi-annual parallax for the stars, is the angle subtended by viewing the heavenly body as from the centre of the earth and its surface, in the first case; and from opposite points in our yearly journey round the sun in the second case.

'Suppose from our base line of 4,000 miles we viewed an object of 4,000 miles distant, the lines of observation would be at an angle of 45 degrees. If the object were at 8,000, or twice our base, then the angle would be 25 degrees, and you will readily see that, given two angles the distance of the third may be calculated, so that a distant and unapproachable object may be ascertained, provided an angle may be detected. This of course you have learned in studying trigonometry. With a finely marked circle, called a protractor, you could read off an angle so small as to deviate but little from two parallel lines. Suppose the angle was measured to be one minute only, that is the sixtieth part of a degree (0 1′ 0″) the two lines would run side by side for more than 21,000,000 miles, in almost parallel lines before they met, supposing they started at the 4,000 miles distance at the base.

'You will understand therefore how difficult it is to measure the sun's distance by these means, when we know that he must be three or four times and perhaps still further removed than the 21,000,000 which an angle of one minute would give. That being so, the angle would be less than $\frac{1}{400}$ of a degree, and, as you may imagine, very difficult of accurate measurement. However, on parallax we must rely for the measurement of distant inaccessible objects. The sun is too difficult to measure *directly*, but we may measure his distance *indirectly*, as I will explain, for since we know the proportional distances of all the planets, if we find the distance of *one* we can calculate all others from that one—the sun included.

'Now Venus is nearer to us than the sun by $\frac{2}{7}$ of our distance from him; if, therefore, we measure

the $\frac{5}{7}$ of her distance from the sun instead of the $\frac{2}{7}$ she is distant from us, we can get a larger angle and get her distance without sensible error.

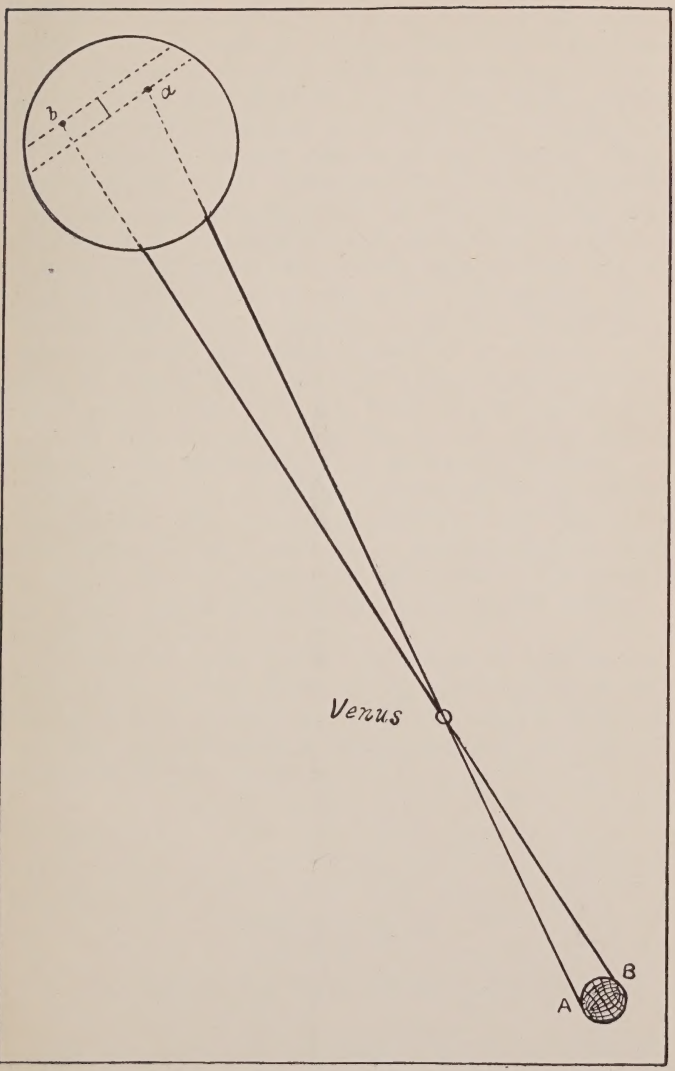
'At certain intervals Venus is in a straight line with the earth and sun, and being between the two we can see her on those rare occasions as a small black spot on the sun's disc. That will be the opportunity for measuring her distance.

'Two observers at wide apart stations will watch for her appearance and report her position on the face of the sun; one observer will see her in one position—the other observer will see her in another position. The wider apart the observers the greater the difference in her position; the task for determination being the difference in the two apparent positions as seen from the two standpoints of observation. Could that difference be measured with absolute accuracy we could arrive at the exact dimensions of the solar disc and the distance as well. In this rough sketch you will see how difference of position in observation will affect the vision, and the different positions of the planet will depend exactly on the number of miles separating the observers.

'This pair of scissors has a long pair of blades and a shorter handle and will roughly represent the case. Venus we will say is at the rivet or pivot; the observers will be one at each finger hole—her positions on the sun corresponding with the tips of the blades. A little extra opening of the handles will cause an opening of the points in a larger, but pro rata degree. It will therefore be advisable to have the observers as far apart as possible.'

'I begin to see', I said; 'but I confess it is rather intricate. Tell me, Doctor, when did you see a transit of Venus across the sun?'

'It was once my good fortune so to do. In the year 1639 it was seen by a clergyman named Horrocks and a companion—they did not, however, fully understand its importance—and whether any other human being has ever seen it is very doubtful. The phenomenon will not be repeated until 1761, and I can hardly hope to live so long.'


b
a
Venus
B
A

As the *plane* of her orbit is much inclined to the plane of the earth's orbit, it is frequently more than a whole century between two such occasions. It was explained to me that although sun, Venus and earth came nearly into line every eight years, yet there was a difference in elevation in consequence of the *plane* of the two planets being different. But the singular result remained that if the transit occurred near the top part of the solar disc, the difference in elevation would still allow a second transit eight years later — we should thus get a pair of transits, but at the next coming into line, Venus would be too far below, and so would pass *under* the sun, and there would be no transit. So also if Venus were moving upward, as she would after a number of cycles, there would occur the pair of transits, and then she would appear *above* the sun and there would be no transit similarly.

Dr Halley had carefully worked out all the above movements, and, knowing exactly when the next conjunctions would take place, was determined that so far as he was concerned full instructions should be in the hands of astronomers to enable them to verify his method.

On leaving the Doctor he pressed upon me a copy of the current issue of the *Transactions of the Royal Society* containing a dissertation by himself on the subject, which book, needless to say, I esteemed a great prize.

CHAPTER X

I CONSTRUCT A PRIVATE OBSERVATORY

I HAD been some time resident in the Royal borough of Windsor, and in about the year 1780 I commenced the construction of a few instruments that would help an amateur in practical astronomy.

My premises had a rather large garden, and I employed therein a carpenter to erect for me a platform at the farther end, so that its length lay due north and south by the compass. At the southern extremity I planted a pole about 8 feet in height and at the top of the pole two projecting pegs about 3 inches apart.

I spared no pains to get the platform quite level and the pole quite perpendicular; spirit level, square and plumb-line, securing for me absolute correctness. The pole was my *gnonom*—such as had been in use for many ages. It had been finished full half a year, and on the 20th December last, an ideal winter's day, I carefully marked on my platform the spot where the beam of sunlight fell after passing between the two pegs at the top of the pole. I am now marking the spot on this 20th day of June, when the day is longest and the sun rises highest; on both days making the mark *at the highest*, so marking exact noon.

I found that at no date did my mark appear farther removed from the base of my pole than on my December date, nor did it ever appear nearer my base than on my June date. Further, I noticed that at noon the highest mark at any intermediate date always fell in the same line, and at regular intervals between my extreme marks. I should say my purpose in having the two pegs on the top was that I was thereby enabled to observe the spot more precisely than if I relied on the shadow of the pole itself. I am now able to draw a line from noon mark in December to my noon mark in June, and this line is an exact north and south line—that is a true meridian line, reckoning truly by the sun.

This same line extended northward indicates the pole of the heavens, and extended southwards would similarly indicate the direction of the South pole. The space separating my two marks show me the altitude of the sun at the winter solstice and the summer solstice respectively. Exactly midway

between the two extremes marked the Spring and Autumn equinoxes.

I am now giving instructions to build me a house of wood, whose side shall be exactly true with my meridian line, and distant about 3 feet from my gnonom, or first-named pole, and I will now describe how I arranged for my transit instrument and quadrant, and how I purpose mounting and using them. I have already said my house is to be four-square, each side facing due north, east, south and west respectively, my pole or gnonom being adjacent to the west face. From my pole to the house there will be fixed a round rod, which I must truly adjust exactly east and west, for it is to bear my telescope for meridian observations which in fact will become my transit instrument. I have already had securely fastened to the tube of my telescope a pair of eyelets, to fit the rod, and you will understand that when all is accurately done the telescope will be free to move up or down at requirement in a line with a meridian of the heavens—I shall be always able to view the North Star, and by simply shifting the instrument, any of the other stars as and when they also come to the meridian, but at no other time.

By means of a graduated circle, marked with degrees, and parts of a degree to as great a nicety as I can attain, and having the same secured to the side of my house central with the pivot of my instrument; and by furnishing an index finger to the instrument that will reach, without touching, the graduated circle, you will see that any movement made by my instrument can be read and recorded by simple observation of the circle.

For example: If when viewing the pole star, the finger points to $23\frac{1}{2}$ degrees; and viewing another star the finger points to, say, $63\frac{1}{2}$ degrees, or as we write it 63° 30′, that is 63 degrees 30 minutes, I learn that the latter star is distant 40 degrees from the pole, simply by deducting the first reading from the second.

The importance of such an instrument and in

connection therewith a good clock for observing the exact time of a star's transit I will explain later.

The first thing I attempted was to observe the pole star and having securely clamped my instrument with the well-known star right in the centre, satisfied myself that my glass was now absolutely north and south. Here, however, came a surprise. Returning to my observations an hour later my star had disappeared! I re-adjusted my glass and again clamped it. In a short time it had sensibly departed from the centre and by and by disappeared as before! The conviction came home to me that the star was not truly at the pole of the heavens as popularly supposed. With infinite pains (to an amateur) I succeeded in so placing my instrument that the polar star described a circle round my object glass, quite close to the edge, and only just in the field of view. Now had I got the true pole, around which the pole star—so called—performed its little journey in one complete day. And from that invisible point, whereat was no star exactly, would all polar measurements have to be taken.

I now proceeded to make quite a contrary kind of instrument — Astronomers call such an one an Equatorial, and this was my method:—By carefully gauging the direction of my telescope as it was fixed when directed to the exact pole as I have described and noting the relative positions of the two glasses—the object glass and the eye glass, I am able to obtain the inclination of the axis of the earth—the axis of rotation. I made a template of this if I may so call it, and conveying the same to the south side of my house, I made a receptacle on the south face, the height of my *object glass*, for the insertion of a rod, like my first rod; and at a little distance I planted a pillar fitted with another receptacle at the height of my *eye glass* for the other end of the rod. Observe, this rod is thus arranged precisely north and south in its direction, and precisely as my transit telescope, as for its inclination, that is to say, its situation was coincident with the earth's axis.

On this rod I mounted, transversely, a second telescope, but not as my first with one movement only; I have had it placed on a pivot, so that, although I can firmly clamp when desired, I may direct the tube to any star I wish, then clamping it, I shall be able to keep that star in view by simply moving the telescope, together with the rod, in its pivot holes.

In the great observatories a similar instrument is in use, but they have a perfect clock-work contrivance which rotates the whole, in the exact time occupied by the earth in its diurnal motion on its axis. That, of course, was beyond my power, but you will see at once how great an acquisition such an instrument must be. The star under observation was maintained always in the field of view, and the observer was left free and unhampered in making his observations. The importance of this instrument I will explain later, as well as detail some of the uses to which I put my imperfect copy.

I had already contributed a quadrant and by following me in my description you easily can do the same. First I procured a piece of hard wood of $\frac{3}{4}$ inch thickness, in the shape of a quarter of a circle. At the apex a true hole for the insertion of a rod to act for a pivot. In order not to be heavy I made it about 18 inches only from the pivot-hole to the outer edge, where I put a small strip of thin brass, and thereon engraved the 90 degrees proper to the quarter circumference. These degrees I also sub-divided to show parts of a degree; in this detail I exercised the greatest care. On one side edge I planted two glasses by means of which I could view a star as well as if it were a proper telescope.

I then made me a plumb-line with a loop, suspending it from the pivot, and having the other end weighted so that it would hang steadily toward the earth. I then made a double stand with journals to support the pivots, and the instrument was complete.

Now suppose I am wanting to know the altitude

of a certain star. I revolve the quadrant to and fro, as the case may be, until I observe the star in the centre as I look through the glasses; the weighted line of course remaining steady, a companion or assistant can read off the exact degree indicated on the quarter scale.

I must not fail to mention another instrument that I named an *areameter*, or sky compass. The frame was of skeleton ironwork, with two rings for the eyes like an opera-glass, only without lenses; and extending outwards for about a foot were two side rods, capable of a lateral movement, like a pair of dividers, and at the end of each a small nob. There was a cross piece attached to one side rod, marked with degrees, and on this cross piece the second rod could be moved and clamped.

The purpose to which I put it was this: placing the rings to my eyes, and presenting the outermost ends towards a pair of stars, or an entire constellation of stars as required, I could measure their distance apart or their *area*. In making the observation I close one eye, the pair of rings serving a double purpose: they availed to keep the instrument steady, beside enabling me to use either eye.

This simple contrivance was very useful, and by its means I was enabled to construct several very accurate star-maps.

For the rest of my equipment, I may mention some compasses, rulers, pencils, drawing pad and a quantity of MS. paper. All these I stowed away inside my house. Then I had a table, a chair and a portable camp-stool for use inside or out, and thus was my little observatory furnished and complete.

CHAPTER XI

A LECTURE ON THE SOLAR SYSTEM; AN EXTRAORDINARY ANNOUNCEMENT

In a room we engaged in the High Street of our town, many most enjoyable and profitable evenings were spent. A few embryo astronomers as enthusiastic as myself were in the habit of assembling to discuss some scientific matter; the first Monday in each month being devoted to Astronomy.

The occasion of which I now speak was what was called an open night when many friends outside our membership were invited.

I was voted chairman, and a brother savant was to lecture on

THE ELEMENTS OF THE SOLAR SYSTEM,

and being fortified with various charts and illustrations he proceeded to relate the main facts as now ascertained, of the component bodies.

He remarked, in commencing, that we were now enabled to describe with an accuracy never dreamed of until recently, the sizes and distances of the planetary orbs, aye, and even their weights also, and with frequent reference to his charts, proceeded to explain as to an audience not very far advanced in the science.

MERCURY is the name given to the planet nearest the sun, yet is his distance no less than 37,000,000 miles. The ancients soon found out that in consequence of his appearing always in close proximity—first on one side, then on the other—and in general almost lost in the sun's rays, that he must be the nearest of all the heavenly bodies. Indeed, if you would see the brilliant little orb, you must seek patiently and diligently, or it will elude

your search. Its diameter has been determined as 3,170 miles, but whether it rotates on its axis in a time similar to the earth, as some think, or whether it takes as long to revolve round itself as around the sun, is still uncertain, but the latter is thought most probable. In that case its movement is analogous to that of our moon, and only one-half of his surface ever enjoys sunlight, and it may be considered doubtful if any sentient life exists on the little globe. Like the metal of the same name, Mercury is the densest of all the planets.

VENUS is the planet next in order, a globe nearly as large as our own, its diameter being about 7,800 miles, and its distance from the sun 66,000,000 miles. It has always been known as the second planet for the same reason that spoke Mercury as being the first: it was never seen far removed from the sun. However, at times she is far enough to be our brilliant evening, or morning star, and at times may even be seen in broad daylight. Her bright surface makes her a very beautiful object; yet her very brightness renders her difficult of close observation, her time of revolution on her axis—that is her day—has, however, been determined as at 23 hours 21 minutes, by reason of a few marks, probably mountains, just visible. The length of her day, therefore, differs but little from ours. The amount of sunshine it enjoys is very much more, and unless some provision is made in the constitution of its atmosphere, the denizens of her surface must be materially different to ourselves, for we certainly would be scorched in a very short time. The length of her year—her circuit round the sun is 225 of our days. Mercury occupies 88 only, and we ourselves, at a distance of 92,000,000 miles, take 365¼ days.

Although our relative distances are now known, yet we are continually changing our distances from each other.

In figure 1, the three bodies Mercury, Venus and the earth are as close to each other as is possible. In figure 2, the whole diameter of their orbits increase their distance by that amount. In figure 3, inter-

Fig. 2.

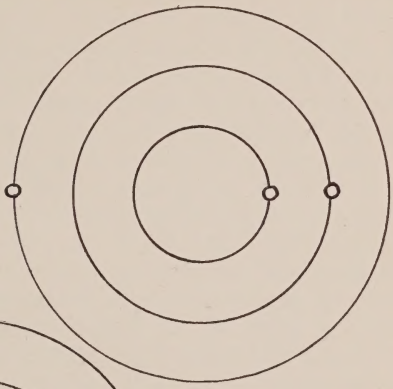
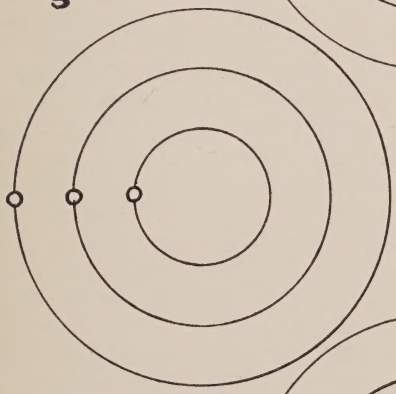


Fig. 1.



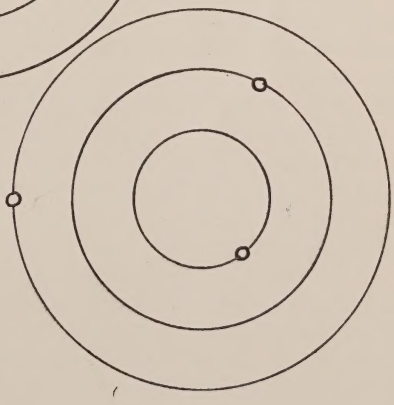


Fig. 3.

mediate positions are assumed, illustrating how the distances apart must constantly vary. At her nearest approach to us, Venus is distant 25,000,000 miles. She then appears very bright and large; in figure 2, add 132,000,000 (twice 66,000,000, her solar distance) and she is consequently 157,000,000 miles from us and of course appears very small. These alterations in position are continually in progress.

It has been noted that multiplying 225×13 and 365×8, we get nearly the same result, in other words, thirteen of Venus' years are about the same as eight earthly years, which shows that every eight years (about) we two, the earth and Venus, are in conjunction. It is a good thing for us (and Venus), however, that a little discrepancy exists, for an exact correspondence would act as a sedative, inasmuch as the oft-recurring *pull* in one direction would tend to an equilibrium; but since there is this little disagreement in the actual time, the point of coincidence is constantly shifting and the danger avoided. In fact no two planets exactly synchronize.

One feature attending the nearness to the sun, of Mercury and Venus, and which indeed proves their nearness, as from our standpoint, is the appearance of phases. They both exhibit, at one time a whole disc, at another the crescent, and again the gibbous form like our moon. Our moon, it must be remembered, is wholly bright when beyond us and further from the sun, and crescent form when nearer the sun. The two planets present the whole disc when beyond the sun, because all of them depend upon the sun for illumination. So that our position with respect to the planets and the moon has to be taken into consideration.

MARS *appeared* to be the next planet in order, but as it was evident the path he pursued was *outside* our earth, the conclusion forced upon us in consequence is, that our own earth is the planet next to Venus—we are the third—and Mars must take fourth place: hence our inclusion with the planets and our place. Furthermore Mars does not exhibit the crescent form as do the nearer ones.

Mars is the ruddy planet as becomes the God of War, and he performs his journey of 440,000,000 miles at a distance of nearly 146,000,000 miles from the sun in 686 of our days. He has seasons like our earth, and the telescope reveals the fact of snow-capped north and south poles. His diameter is about half of ours, and his day almost the same as ours.

The next in order is JUPITER (unless the imaginary planet some are looking for, nearer than he, can be found). He is the biggest of all and is distant from the sun about 495,000,000 miles. He sometimes appears to us as large as Venus, notwithstanding his immense distance, and her comparative nearness—and we earth folk so near the sun in comparison to him, that it is doubtful if any Jovian astronomer would ever be able to see our globe. Jupiter has a day of only ten hours' duration—five light and five dark; and he has four moons to lighten his hours of darkness. His diameter is 92,000 miles (ours is less than 8,000), so that bulk for bulk he is 1,400 times larger than the earth.

Last of all comes SATURN, and perhaps fitly so, since he is different to all others, as to his furnishing and retinue. He has no less than eight moons in attendance, and in addition a ring of light of marvellous construction, the like of which is no where else seen in our system, and composed some say of countless myriads of small satellites, kept in equilibrium by gravitation combined with startling rapidity of movement around the body of the planet. It was this ring that so puzzled Galileo, who, with his imperfect telescope, first thought the planet to be triple, and then that it had handles like a round soup tureen.

While the lecturer was thus relating the details of this last planet a note was forwarded to myself, the purport of which astonished me not a little, but I was perforce obliged to restrain myself for a while.

My attention was recalled to the matter in hand by my friend displaying two charts, miniature copies of which I here reproduce.

FIG. 1

Arc of the Sun
Jupiter.
MERCURY
MARS
VENUS
Saturn
EARTH

FIG. 2

Distance from Sun in Miles.
Sun
Mercury 35,000,000
Venus 66,000,000
Earth 91,000,000
Mars 139,000,000
Supposed Planet 275,000,000
Jupiter 475,000,000
Saturn 871,000,000

Figure 1 shows the relative sizes of the planets, etc., and figure 2, their respective distances. The address being brought to a close by a reference to the conjecture as to a lost planet, room for which was so apparent in the great space existing between the orbits of Mars and Jupiter. The apocryphal planet, some named 'Pluto,' but so far no trace of it had appeared. Whether or no such a body existed, the idea strangely enough had taken hold, and many a telescope was nightly in requisition in serious search.

The lecture concluded, I rose to my feet as most thought to propose a vote of thanks, but holding forth my letter I said:

'Ladies and Gentlemen, I have here a communication from a friend who has but just now left Sir William Herschel, and I have to announce nothing short of a revolution! In fact, a revolution in revolutions, for Saturn has been dethroned, and another reigneth in his stead! No longer is he King of the Confines! From time immemorial he has been our outermost member, but this amazing, not to say startling information, now reaches us. In short, the so-called "Comet" that Herschel imagined he had found, has been declared to be a planet, and that a large one, and at a distance about twice that of Saturn's.

'Kepler, among others, surmised, as we have heard to-night, that one might (and should) be found between Mars and Jupiter, and whilst assiduous search has been made for such a one, no single astronomer contemplated the find that has come to Herschel.

'While star-gazing with his telescope he espied a small object, not bright enough for a star, and a little better defined. He, supposing, as you know, the stranger to be a comet, communicated the matter to the astronomical world; but on larger powers being brought to bear upon the object, behold a planetary disc was revealed. Searching for a small globe, he has found a giant one; expecting one comparatively near, the one he has found is at such

a distance as to nearly double the extent of our system at once!

'It is thus men's names are made immortal!'

I then dismissed the meeting, and as I was appointed to lecture at the next assembling I requested that it too might be an open one, and I would ascertain more particulars in the meantime.

CHAPTER XII

HERSCHEL SHOWS ME SOME DOUBLE STARS AND THE PLANET URANUS

NOT long afterward I paid a visit to Sir William Herschel's residence at Slough, to learn for myself particulars of his latest discovery. He was very busy, but received me with great kindliness. I inspected his beautiful instruments, and gleaned a lot of information that was new to me. I told him I hoped if possible to see the new planet.

'That indeed you shall', he returned, 'although it is not *new* by any means. Since I first saw it, it has transpired that others have both seen and charted it, but his planetary character was not so much as suspected. Flamstead, Mayer and Bradley have seen him several times, but he was listed as a *star*. On trial, the place of their so-called star was *vacant*—their star was undoubtedly the unsuspected planet.

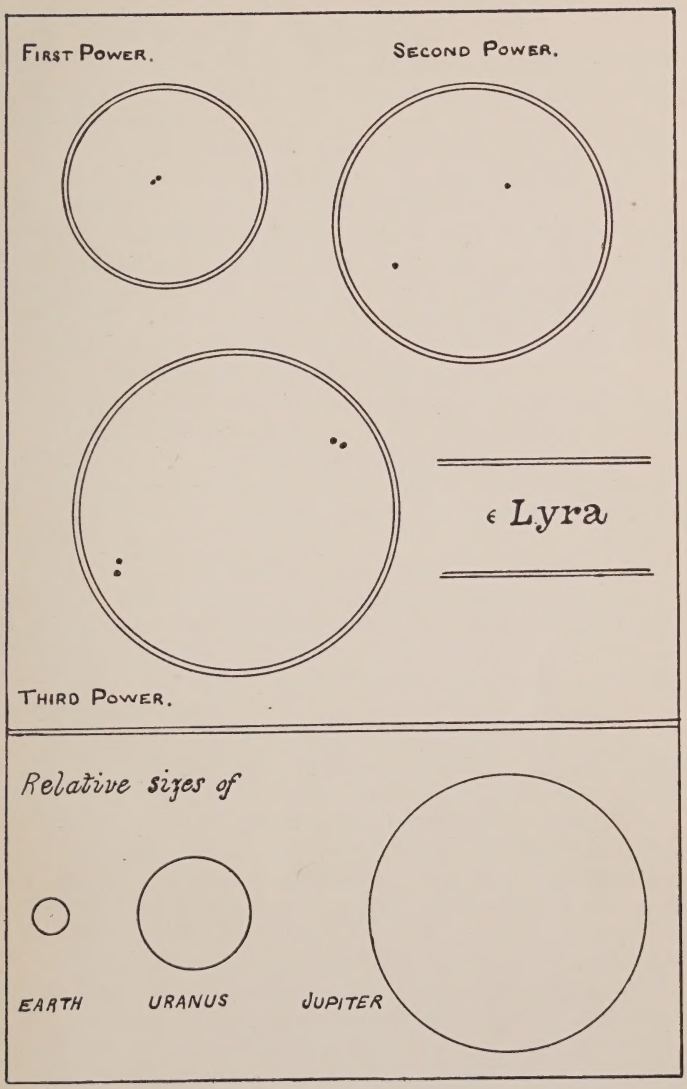
'The work I am now completing is a catalogue of *double* stars ——'

'*Double* stars, Sir William?' I exclaimed.

'I have already a list of 700 such bodies, and since I am continually adding to the number, I anticipate that many thousands will be discovered as time goes on.'

As though expecting the question to which I had nearly given utterance, Sir William continued:

'I will be glad to show you a few. One of the


First Power.
Second Power.
ε Lyra
Third Power.
Relative sizes of
Earth
Uranus
Jupiter

easiest to see is *Mizar*, the middle star in the tail of the Great Bear. *ζ Ursa Majoris.*'

'The Tester', I interrupted, remembering the old Arab name for the small companion star, as proof of good eyesight.

'I do not refer to the "Tester", that is to say *Alcor*', said the astonomer; 'I am talking, not of stars that are simply close, optically, and as in the case you mention nearly a third of a degree distant, but of actual double stars, *pairs of stars* that seem to be *one* to the ordinary sight, but really *binary* systems. *Mizar*, as I was saying, is such a pair; that is to say, to the naked eye *Mizar* is but one; but look through the telescope and see.'

I approached the instrument which he had just re-adjusted, and looking, beheld what astonished and charmed me. Verily *two* stars, but so close, and yet so distinctly separate. A picture of absolute beauty.

'And do you tell me you have seen 700 such as this?'

'Yes', he replied, 'some pairs are of the same colour, but others—and most of them—vary, one being red and another white; or one red and its companion blue.'

'And are they companions in fact, or only apparently so?'

'They are without doubt companions, since they revolve around one another. There is a centre of gravity common to both, and many pairs have had their times of revolution computed. *Castor* is another such, and the pair cannot revolve once, in a shorter time than 250 years. The one you viewed, *Ursa Majoris*, revolves once in 58 years. *η Coronæ* is a double of 43 years.'

Meanwhile the telescope was directed to another pair which I observed to be a beautiful yellow with a blue companion, and yet another pair a crimson and its companion green.

Sir William then adjusted a second telescope and his large one also, both on the same star. Looking at his bidding through the smaller one I saw a small pair quite close together. Then I was directed to

view with the large instrument. What wonder! FOUR STARS! Each component of the pair was itself double!

'Wonderful!' I exclaimed. 'And does the law of gravitation rule thus far, compelling their motions, binding them together?'

'Undoubtedly', he gravely replied, 'gravitation rules and holds sway in all God's universe, but the thought that impresses me, and awes me is this: we can just see these pairs of suns, so close as in some cases to be barely resolvable, yet were we transported to either one of them, the close companion would have receded from us, so as to be, from our then standpoint, only a distant star.'

I had quite forgotten the object of my visit whilst contemplating these new wonders, but Sir William had the new planet in the field of view, and requested my attention.

'You may see now the planet last found; I regret, however, the night is not favourable to see any of his moons as well.'

While gazing silently, as but few ever had done on this new member of our system, I said to myself, or rather my thoughts thus wandered:

'So this distant planet, twice as far as Saturn, has a number of satellites, too!'

The night was fast getting late, and I was preparing to depart, but my kind host, putting away his tools and papers, invited me into his inner study, and with great pains instructed me in other matters, notably in the matter of the sun's journey through space, and in the *proper motions* of the stars.

As, however, it occurred to me as suitable to relate these discoveries in the form of a lecture to our Society, I refrain from stating them now.

CHAPTER XIII

BODE'S LAW; NAMING URANUS; A NEW FIND; THE NODE

INQUISITIVENESS, as well as deep searchings, is a characteristic of our modern astronomer, as well as of the ancient. In all time, what has not been understood has been made subject of hypothesis. A supposition of a truth has been advanced, and subjected to a trial, and if unable to bear all possible tests it would be discarded and another supposition tried. What has been called an empirical law, that is the result of trial, has been put forward by Bode; an idea worthy of Kepler himself.

The idea was put first into form by Titius of Wittemberg, who, noticing the regular increase in distance in a certain gradation, assumed by the planets in their positions as from the sun, framed the following scale. It was published, however, by Bode, and is known as Bode's law.

Says Titius: 'If we examine the distances of the planets we find in almost all a proportion between their distances apart and their corporeal magnitudes. If the distance from the sun to Saturn be divided into a hundred parts, then Mercury is distant four such parts from the sun; Venus $4+3=7$ parts from the sun; the earth $4+3+3=10$; Mars $4+3+3+3=16$.' Then Jupiter should be $4+24$, but he is twice as far, and we come to a departure from a progression previously so exact, although Saturn takes his place at $4+96$, which is correct.

Set out as follows:

0 3 6 12 24 48 96

and add four to each we obtain

4 7 10 16 28 52 100

add the several names

Mercury, Venus, Earth, Mars, *Jupiter, Saturn,*

and the interregnum at once becomes apparent, for at

twenty-eight we find no planet! Can we suppose that the great Architect has left this space void?

And since the 'admirable proportion' was continued by Jupiter and Saturn, his impression was confirmed, that although evidently there was no large planet (or it would be seen), there must be some 'telescopic' ones. It was in 1772 that Bode published the above 'law'. It was considered interesting, but led to no immediate results. Now, strange to say, the distance of Herschel's planet was such as to revive the idea, for the same progression was found to exist:—

Saturn stood at $96+4=100$.

Herschel's stood at $192+4=196$.

So there cannot be much doubt there is something in it.

* * *

My first appearance as lecturer at our Society was not a very important affair, and I will not refer to it in detail, but the following particulars were brought to light.

Astronomers had not been long computing the orbit of the new planet. Its angle of parallax gave for its mean distance 1,800,000,000 miles. Its diameter 34,500 miles, and the number of its satellites at least four, some said six, and it would occupy no less than eighty-four of our years to complete one circuit round the sun.

For some time the planet bore the astronomer's name and was known as *Herschel*. He, however, preferred to call it *Georgium Sidus* in honour of his king, but the elevation to the Company of the Gods of neither monarch or subject commended itself to astronomers generally, and so by the name *Uranus*—the father of Saturn and grandfather of Jupiter—was it ultimately known.

The computation of its orbit revealed the fact that it was an eccentric ellipse; its *major axis* differing from its *minor axis* by 170,000,000 miles.

Uranus soon proved himself, however, to be a wayward member of our system, for a mysterious *lagging behind* in his journey puzzled the fraternity for a long time.

Kepler would have said, 'There *must* be a reason.' Newton would say, 'That reason must be *found out*.'

* * *

January 1st, 1801. News has just come to hand that a small planet has been discovered between Mars and Jupiter! A good beginning this for the new century! I must enquire particulars of this.

* * *

There is a term used by astronomers demanding explanation: The *Node*. Let me give a rather full exposition of what I understand that to mean. I will state at the first that all planets in their courses move in a plane that *cuts* the sun's centre; each planet has its own plane—no two planes are the same—but every plane has the sun's centre in the same level. In like manner all satellites move in planes that *cut* the centres of their respective primaries. The moon, for example, if seen one night at an elevation of 60 degrees above the horizon, would, could she be observed on the opposite side of the earth twelve hours later, be *depressed* just 60 degrees below their horizon, or 60 degrees towards the opposite zenith. So that her path is exactly concentric with the middle of the earth. The halo represented around the head of a saint on the contrary is placed out of the centre, if not altogether removed. Perhaps I can best liken the matter by two boys' hoops of different sizes, placing them on a table, one inside the other. They are on the same *plane* while so resting, and the outer one would entirely shut out the view to any small creature situated on the edge of the inner hoop. Now if we slightly lift the hoops and incline them ever so little, they no longer coincide all the way round. Mathematically, only at two points, equidistant are they dead opposite. These two points are the *Nodes* of the two circles the hoops represent.

The minute creature I supposed on the inner hoop, would, in the inclined position, be able to see in all situations excepting at the nodes.

As the moon (around us) and all the planets around the sun, move in planes that cut the sun's

centre, it is easy to perceive that our earth and Venus may be in a line, and Venus, the inner body, would hide from us a portion of the sun's disc, which event is called a transit as we then observe her moving across his surface. When the earth and moon and sun are in a line, the moon being central, she, by reason of her size and nearness to us, occasions a more or less total eclipse of the sun's body. On other occasions of such a position—only that the earth is central and the moon outside, we have the phenomena of a lunar eclipse because, the sun shining direct on the earth always throws the shadow of our earth behind, and the moon being opposite passes through the shadow.

I may now explain shortly why we do not have a transit of Venus more often, and why a solar and lunar eclipse at every lunation does not come to pass. I have said the several bodies move in slightly different planes, hence if to-day they are in a straight line (dead opposite) we have an eclipse, or a transit, but next time the line of conjunction is a little higher (or lower) and we miss the actual eclipse. Could we see the central body—moon or planet—we should observe her very close, but not in front of the solar orb. We, of course, are always opposite the sun, the sun's apparent path being called the *ecliptic*; when the moon or planet crosses the ecliptic she, or it, is in her node; when crossing to the northern side—in her ascending node (☊); when crossing back again, in her descending node (☋).

CHAPTER XIV

HOW TO TELL THE STARS BY THEIR NAMES

EVERY one knows that the stars—the host of heaven—have been grouped into the sets or constellations bearing their several names—many of them the most fanciful. But however crudely the naming may have been done by the ancients, they have been little

interfered with in later times, forming as they do, a ready means of distinguishing the stars one from another.

I had to deliver a lecture entitled

HOW TO READ THE STARS,

and I commenced by saying:

Every young astronomer should know how to recognize as many of the stars as possible by *name*. It gives a charm to the science, to which nothing can compare. A solitary traveller is no longer altogether alone if in an evening's walk he can tell this star or that planet and call them by their names. They become his friends.

One of my acquaintance had watched Orion and Sirius for months, until in due course they no longer remained visible as night stars. Others had, as it were, taken their places. However, one night late in the year, whilst walking home, he espied the magnificent constellation just risen in the east. With rapture he exclaimed 'There's Orion'. It was as if an old friend had come back and had greeted him! So may all of you view them. It will now be my purpose to give a few general directions how to tell the stars in as simple a manner as I am able.

On a calm evening, free from clouds, just as the twilight deepens, a few stars will appear; all around being clear sky. These early visitants will be the stars of the first magnitude. As the darkness increases, many more—coy ones—show themselves; these are second magnitude stars; then, finally, the host of heaven, according as the clearness of the sky may be.

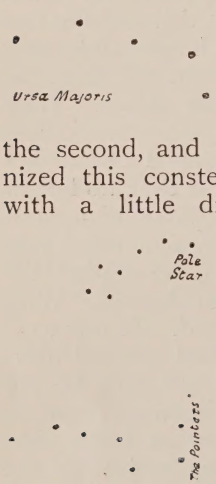
We must know all the first magnitude stars by name that appear in our hemisphere, without exception, or we shall be poor astronomers. Their names are: Capella, Vega, Arcturus, Castor, Procyon, Betelgeuse, Aldebaran, Rigel, Sirius, Regulus, Spica, and perhaps Denebola, Antares, Altair and Aries (Arietis).

This may seem a formidable list, but they are all quite easy to distinguish. They are not of

equal brightness, yet they are all much brighter than stars of the second magnitude.

We must have recourse to stars of the second magnitude to know those of the first; for stars, like folk of the *genus homo*, are known by the company they keep.

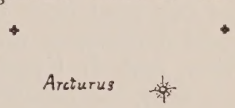
Let us watch, therefore, for the Great Bear (Ursa Major), sometimes called the Plough, which it more nearly resembles. This familiar constellation will make its appearance immediately after a few of the first magnitude. There are seven prominent members of this group, six of the second, and one of the third. Having recognized this constellation, we may be able to trace, with a little difficulty perhaps, the Little Bear (Ursa Minor), of almost identical shape but in the reverse order, and smaller, as though a lady bear at a distance waiting for her lord. Now observe, the two stars farthest from the tail in Ursa Major are almost in a line with the end star in the tail of Ursa Minor. Hence they are called the *pointers*. That end star they point to is Polaris—the Pole Star. Having accomplished this, we shall have made a good start. The Pole Star we must be certain of before all others, for, although not very bright, it is the central star, the pivot upon which all others turn. When facing the Pole Star we are facing the north; the south is behind us. All other stars, as also the sun, moon and planets, rise on our right, that is the east, and set on our left, that is the west. I should say, however, that some stars are called circum-polar stars because they revolve round the pole so nearly that they never go below our horizon. In a sense, therefore, they neither rise nor set.



Knowing the Pole Star we can easily tell the cardinal points of the compass; hence its great

importance as a starting-point. Most schoolboys know thus much, but few I ween will trouble about more.

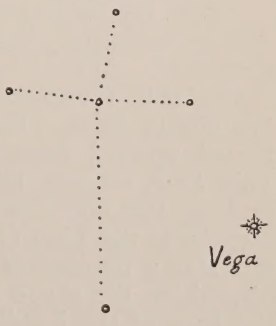
I am anxious, however, to get to our first magnitude stars, and number one shall be *Arcturus*, in some people's estimation the second brightest in our hemisphere. Once recognized it should never be forgotten. Prolong the tail of the Great Bear with a little additional curve and the first bright star is *Arcturus*, in the constellation of the 'Hunter' (Bootes). It may also be recognized without the aid of the Bear, for it is attended by two clearly discerned stars, making with it an unequal triangle, thus: The two small stars are white, *Arcturus* is ruddy.



Capella is a very bright star, competing with Arcturus for second place, and will be found just opposite that star with the Great Bear between them.

If we would find the stars we must make a habit of drawing imaginary straight and curved lines. In this case a straight line from Arcturus to Capella will bisect the Great Bear.

Vega is our third bright star, indeed by some said to be *the* second brightest (for Sirius is the brightest of all), and may be found thus: A nearly straight line from Capella, slightly convex to touch the pole-star, will lead to Vega. We next observe by way of sky-mark, that Arcturus, Vega and Polaris form a large triangle, with only small stars in the enclosed space, and, moreover, these two stars are nearly always in sight because of their proximity to the pole. In fact, Capella never sets, but just touches the horizon at one time and the zenith at another. Close to Vega, by which also it may be easily identified, is the constellation of the 'Swan'



(Cygnus). Its five principal stars being in the form of a cross, covering a considerable expanse; Vega, the penitent star, always at the foot of the cross, being situated towards the base. In rising in the north-east the cross will be lying down, the top to the north; when southing it will be more upright, and in setting the foot of the cross is the first part to disappear. This constellation is noted because of its inclusion of our nearest neighbour (save one), namely, '61 Cygni', distant merely 40,000,000,000,000 miles! It would appear proper to know somewhat of our next door neighbour, but in this matter our best telescopes make poor means of communication, and 61 Cygni happens to be small, although so near, comparatively.

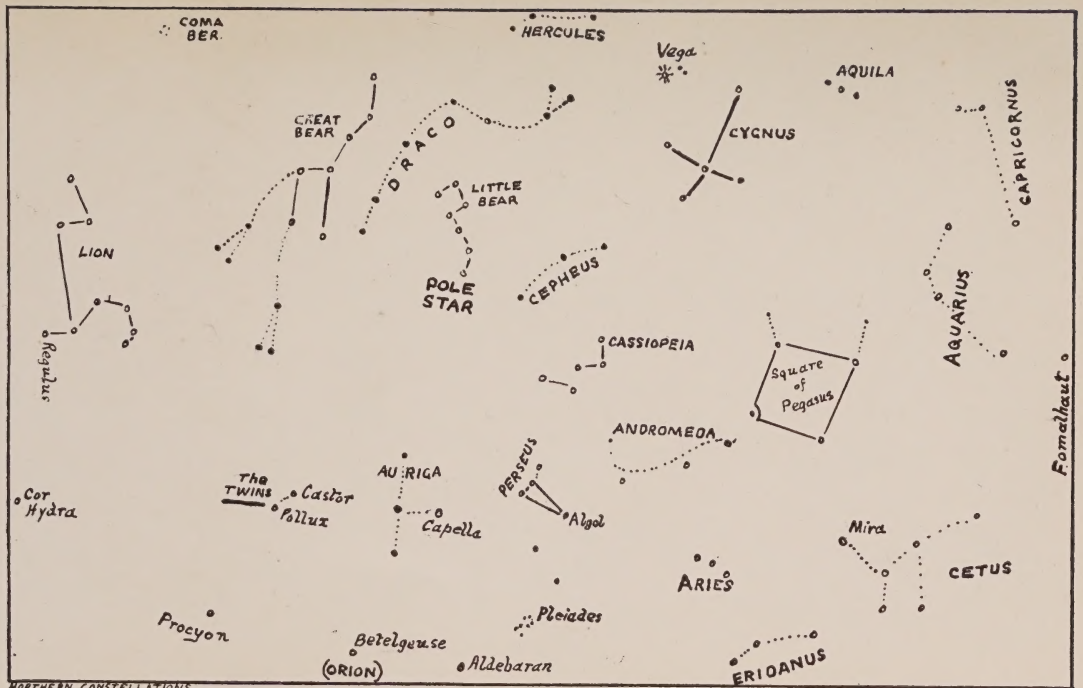
Here, I may remark, it does not follow that because a star is small, it therefore is farther off. Capella, for instance, a really bright star, and which we might suppose to be near, is actually situated at a greater distance than many a star just twinkling, and Zollner has demonstrated that our resplendent sun, if viewed from Capella, would appear to such an observer but as a fourth magnitude star.

Let us now locate *Cassiopeia.* It will be found opposite the Great Bear, with Polaris in the middle, its principal stars nearly resembling the letter W, and with some adjacent stars compose what is called Cassiopeia's chair.

When the beginner has learned thus much he will be sufficiently interested to pursue the matter farther.

We will therefore hunt up a few more first magnitude stars. Remembering that a line continued upward from 'The Pointers' show us the Pole Star, we now take the pointers as before, but prolong the line downward, and it will lead us to *Regulus* in the Lion (Leo). Note in connection with this star a number of smaller ones, making in their disposition the shape of a sickle—Regulus being at the base of the handle.

Spica in the Virgin (Virgo) will be seen by turning our back to the Pole Star, and by prolonging a line



NORTHERN CONSTELLATIONS.

C.J. GRIFFITH.

FIG. 1.

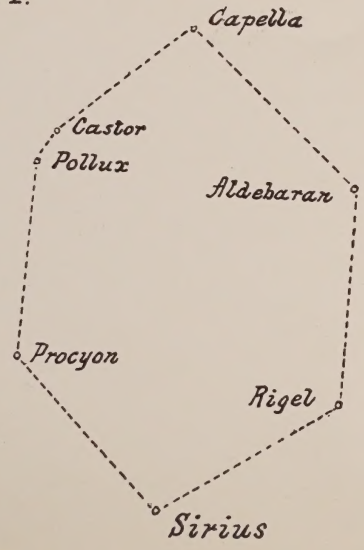
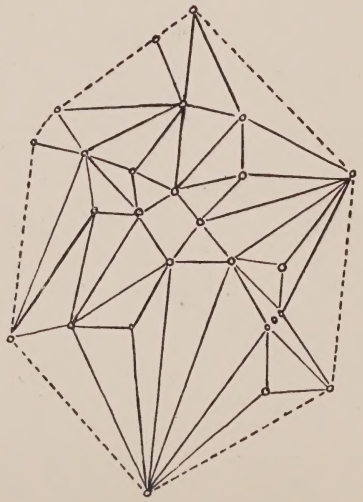


FIG. 2.



passing through Arcturus, it will be seen shining almost alone, except for very small stars.

Now, producing a line from Regulus and passing through Spica, we come next to *Antares* in the Scorpion; continue the line again, and south of Vega we reach *Altair* in the Eagle (Aquilæ).

Vega, Altair, Antare and Arcturus, will form a large irregular square.

Arcturus, Spica, Regulus and the Great Bear (the inner member) will form another irregular square.

You will soon work out for yourselves all manner of shapes.

* * *

The Astral Diamond

I will now describe to you what I think to be that part of the heavens the richest in prominent stars, and also the wonderful configuration of them; the most suitable time for viewing them being the early months in the year in the mid-evening.

The diamond formation will then appear in the following situation:

Almost in the zenith our friend Capella, and just skirting the southern horizon, *Sirius*, a star two or three times brighter than any other star.

A third of the way upward from Sirius, on either side, projecting outward at about 40 degrees, are two bright stars; on the left, *Procyon* in the little dog (Canis minor), and on the right, *Rigel* in Orion.

Another third way upward — this time nearly direct—and on the left we have the 'Twins', *Castor* and *Pollux*, and on the right above Rigel, *Aldebaran* in the 'Bull'.

Upward again—the remaining third of the way —branching inward from each, brings us to Capella, and the diamond is complete. It is furthermore enriched by having the whole of the constellation of Orion within its boundaries, the innermost of which is *Betelgeuse*.

I commend the study of this unique combination to your careful and best attention, forming as it does an immense diamond of light—a celestial

jewel—and occupying nearly a third of the visible heavens from north to south and almost a fifth from east to west. I then produced a plan showing the relative positions and another the many facets, as it might be, tipped with stars.

Once a month the moon may be traced wending her way through the formation, at times *occulting* or hiding by her body one or more of its members. Not infrequently the planet Venus and the moon will together be within its boundaries, and since the ecliptic passes through our diamond—and all the planets journey quite near the ecliptic—it is quite possible that the whole family of planets, including Mercury, might at one and the same time conspire to render this combination a galaxy indeed! When they were all within its confines I cannot tell, nor when the event will happen next, I know not; but such is the exactness of the science, that were it worth the labour, the time could be calculated and accurately foretold.

I desire you should be able to search out the 'Square of Pegasus'. It is situated below Cassiopeia and between Aldebaran and Vega. Immediately between Capella and Pegasus we find *Perseus*, having three bright stars nearly in a line, and at a short distance shines *Algol*, forming in connection with two of these three a triangle. Algol is called the 'demon star', because its light varies from the second to the fourth magnitudes in a few days. Indeed a careful watcher will observe changes in its brilliancy in a few hours.

Between Perseus and Pegasus is a line of stars at about equal distances, which, with Algol, produces on a large scale a figure like unto the Great Bear. Below Algol and towards Aldebaran shines the *Pleiades*, wonderfully vivid, of various colours, known to most students yet possessing no star brighter than the third magnitude—*Alcyone*—which has been likened to a hen with her attendant chickens.

Thus I concluded my budget of star names, remarking that a whole year would be well spent in mastering their whereabouts.

Not at one time can they all be seen, for daylight intervenes, shutting the late risers from view, but in the course of a few months they may all be traced.

Job in his sacred poem refers to the Pleiades, Arcturus and Orion. The Almighty Creator is said to call *all* the stars by their names, and astronomers failing in this can yet refer to any *visible* star and know it from its fellow by a sign or a number, such as '61 Cygni' or '1830' of a certain list. But verily they are countless as the sands on the seashore for multitude!

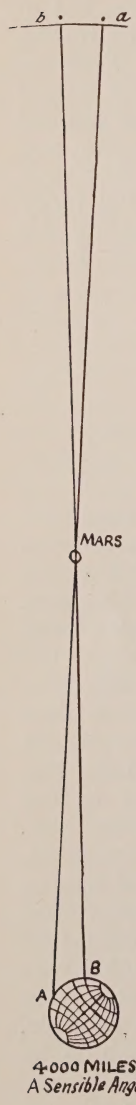
CHAPTER XV

THE DISTANCES OF THE STARS AND HOW ASCERTAINED; APPARENT FIXITY—REAL MOTION

I WAS booked for three lectures, the second one bearing the title heading this chapter, but it was not to be a dry statistical discourse the title would appear to indicate. To begin with: 'Their distances, and how to measure them'. As you know, to learn the distance of our own sun by its parallax with the radius of our earth for a base line, was sufficiently difficult as to be almost abortive; much less then would such a line serve in the case of the distant stars. Recourse was therefore had to a base line of 190,000,000 miles; this being to hand in the diameter of the earth's orbit—a most ingenious idea. At any two periods of the year, six months apart, such as spring and autumn, or summer and winter, the earth is at opposite sides of the sun, and of course in one part of its orbit would be approximately that distance removed from its position in the other part of its orbit. A visual line directed to a star from position one would, it is thought, show a sensible, perhaps a considerable, disparity in its position as when viewed from position two, due to parallax.

The almost inconceivable answer to such an inspection and trial showed, however, that the

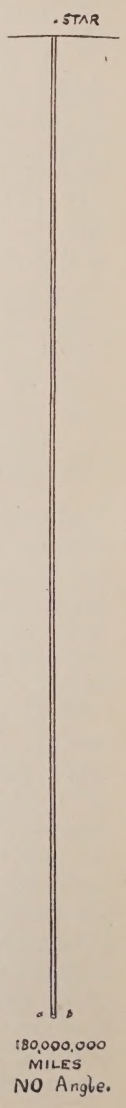
distance of the stars is so remote that no parallax is discernible at all except in very few cases. Let us see now what that means. Suppose an observer on one of the stars, properly equipped with astronomical instruments and able to view the earth, would see the immense orbit of 190,000,000 miles contracted to all but an invisible point! Their distance therefore must be *immense!*



The star that yields the largest parallax is *a Centauri* in the southern heavens and the angle subtended 1″ at the outside, perhaps less.

If, however, it is 1″ it means that it is distant no less than 100,000 times the diameter of the earth's orbit, that is 190,000,000 × 100,000 miles or 19,000,000,000,000 miles. The small star, 61 Cygni, gives $\frac{6}{10}$″ only, and is almost twice as distant. *A Lyra* (Vega) $\frac{1}{4}$″ or more than twice as distant again —the vast host give no sensible parallax at all; but I may remark that supposing we could observe even one-tenth of a second the distance would work out at more than 2,000,000 times the distance of our sun.

The two diagrams show how distance affects the angle in parallax; Figure 1 supposes Mars as he would appear viewed from two points on the earth. He would appear from A at a, and from B at b. And in Figure 2 a line drawn from each side of the earth's



orbit is practically parallel the one with the other, and therefore gives us no angle. (An angle of $\frac{1}{10}$ of a second is but the tenth of a 60th of a 60th of a 360th of a circle.)

* * *

The difficulty of appreciating distances is very considerable — great distances soon overwhelm us, perhaps the most easily comprehended is the diameter of our own globe, which for convenience we may suppose 8,000 miles. What with the records of travellers, and the quick transit enjoyed, now that steam has come to be harnessed in our service, we are forcibly made to apprehend what 8,000 miles may signify. Once round the earth will be three times the diameter, or 24,000 miles. We are aware that the moon is distant about thirty times the diameter of the earth, so $8{,}000 \times 30$ and we have 240,000 miles for the moon's distance. Perhaps that is somewhat comprehendable. No other distance is nameable but goes at once into millions, and imagination fails to grasp anything like a correct idea.

ONE MILLION equals the moon's distance four times repeated—and a trifle beside.

Let us suppose that fourfold distance repeated for a second million ; then traverse the same space for the third million ; again for the fourth, fifth, sixth, seventh, eighth, ninth, each time beginning at 0 and ending at a million—and in all this we have but reached the tenth part only of the sun's distance. NINE times more are we to commence at 0 and pile up our stages of NINE MILLION MILES before the source of our light and heat is approached. Space is infinite ; celestial distances are illimitable ; man only, together with the creatures of the dust, his fellow sojourners, appear by contrast to be less than atoms in the balance and as altogether vanity !

We will now proceed to their motions.

We talk of the 'Fixed Stars', but we are forced to acknowledge that to so speak is not absolutely correct. There is one only excuse for so speaking, namely, that they appear to be 'fixed'. In point of fact, there is *no fixity*. All is in motion ! Fixity is

only a comparative term. It may be that a thousand years will reveal little apparent change, yet a close examination shows that many stars are in different situations from those recorded by the ancients, and examination more acute shows that even in a few years the motions may be measured. As a mechanical necessity it is now admitted that all the host of heaven must be moving. That we do not easily see it is another evidence of their immense distance. Herschel first instructed me in this: A movement that is discernible is called the stars' 'proper motion'. One star may be travelling to the left of the line of sight, another to the right—some are approaching, others receding. Some of the double stars—the Binary Systems—revolve about their own centres of gravity, and at the same time possess a *proper motion* common to both. Since the direction of motion is various, it cannot but result that after many ages (æons), the constellations themselves will present different aspects. Furthermore, Herschel proved that our own sun participated in the general scurry of the spheres. It might appear that it was not easy to demonstrate this, but if we consider the following illustration it will not appear so difficult:

Suppose a large circular lake, several miles in extent, and around the outside edge of which are a number of lights, placed so closely as to appear from the centre almost contiguous. In the centre of this lake the observer is placed on a raft or boat, which is connected with the land, north, south, east and west, by four stout ropes. Suppose that the ropes on the north and south be allowed a movement to and fro of several yards. The observer will soon be sensible that he is moving alternately first in one direction and then in the other. Ropes east and west are, however, allowed a different motion and one so slow and gradual as to suggest no sensation of movement. We will say that the east rope is paid out 1 inch and the west rope drawn in 1 inch daily. In thirty days the raft would be no longer central by 30 inches, but there would be no sensible

difference. In a year 365 inches or 10 yards 1 inch would be the measure of removal from the centre; still, in so large a sheet of water, the only sensible motion would be the one effected by the swaying north and south ropes.

We will suppose now that 10 years have passed, and the slow paying out of the east rope would have amounted to 100 yards 12 inches, allowing two leap years. A close observer would now announce the fact that they were slowly approaching the western boundary, BECAUSE he noticed that the *lights* on the shore did not appear quite so close together as before, whilst those north and south remained as at the first. Those to the west were in fact *opening* out.

In just such a way as in this illustration do we know that the sun and the entire Solar system is in motion towards a certain point in the heavens, namely, towards the constellation Hercules. The stars in that direction are slowly opening out, and in an exactly opposite direction they are closing in.

The speed with which our system is travelling is calculated as 154,000,000 miles in one year, and that rate represents the *proper motion* of our sun as it might be viewed from a neighbouring star.

Whether this stupendous journey is in a straight line through the universe, or whether our course is bent to an orbit around some distant and controlling centre it is impossible to determine.

* * *

The 'Stars in their courses that fought against Sisera' may have been the planets (vide Astrology), or was the sacred Songster skilled as in modern astronomy?

The Size of the Sun

The diameter of our sun is 860,000 miles.

The words in the Bible number over 810,000.

So that—were it possible—the whole of the Bible could be written across his face, with a MILE between *each word.*

CHAPTER XVI

DISCOVERY OF THE PLANETOIDS: ADAMS AND THE DISCOVERY OF NEPTUNE

My note book, devoted to new events, has been in requisition a great deal lately. The small planet named *Ceres* found on January 1st, 1801, by M. Piazzi, was not long alone, for on March 28th, 1802, Dr Olbers, of Berlin, found another at about the same distance from the sun, and this anomaly of two small planets journeying in the same track gave rise to the suggestion that a larger planet had one day existed there and had met with some catastrophe rending it to pieces—an idea that was greatly strengthened when in the following year two other *planetoids*, as they are called, were discovered. Dr Olbers says on this subject 'We might expect to discover in the same region more such fragments describing an elliptic orbit round the sun.' I was rather sorry that Herschel's son and many others looked upon the suggestion as a dream only, giving no encouragement to further search.

* * *

Forty-six years have passed since the finding of *Ceres* and no less than twelve planetoids have been discovered, some of them very minute, only as large, say, as Middlesex, or as a feudal lord's domain, and some appear to be, not round, but angular in shape, and rather as a fragment than a whole world—but other matters press, and I must proceed.

* * *

I had the good fortune to meet Mr Adams at a tea table at a public restaurant, and as I had heard of him as a mathematician of high repute, who was endeavouring to unravel the causes of the somewhat

erratic movements of Uranus, I thought it most opportune.

You remember that a curious lagging behind was soon observed in the planet's journey, and it was confidently stated that the solution of the mystery awaited some lucky and painstaking observer. I soon took the opportunity of my chance introduction to elicit much information.

To my query why astronomers were so certain of finding another planet outside Uranus—for that is really what has been determined upon as a sufficient cause, he replied:

'Did you ever feel a mysterious pain and not know that something was amiss with your health? Or did you ever hear a thunderclap and not know there was electricity in the air? Did you ever notice a change in the barometer and not know that an atmospherical disturbance was in progress?' 'Similarly', he proceeded, 'since *inertia* is characteristic of inert matter, a globe revolving round the sun as does Uranus must obey the known law of gravitation. To suppose otherwise is to endow an inert mass with sentient feelings, or properties—with a will and determination to go hither and thither, which is absurd. All matter acts upon all other matter in proportion to mass and distance, and universal gravitation is the only power known to us that can deflect a moving body from an original course, whether that course be a straight or a curved one. Now Uranus moves in an unaccounted manner. Saturn deflects Uranus; Jupiter deflects Uranus. These interferences we know and can account for; but Uranus takes a course *outside* his mean path, therefore a large body must exist exterior to himself that controls his movements, drawing him outward.'

'You appear very confident', I remarked.

'We have sufficient ground for our confidence,' was his laconic rejoinder.

* * *

At a subsequent interview Mr Adams gave me a few further particulars, and I was permitted to look

at some of his extensive calculations, which were of a voluminous character, involving a lot of work. He told me that others were interested in the problem, which was none other than to fix the position that the disturbing planet must be in, and considering, according to Bode's law, it should be about twice as far as Uranus, it was a problem of no mean difficulty.

It appears that a Rev. Dr Hussey had written the Astronomer Royal on the subject, and Professor Challis of Cambridge had also done the same on behalf of Mr Adams. The Astronomer Royal, however, if he thought such a planet existed at all, did not believe that at so great a distance it ever could be found, and so gave no assistance. Not easily repressed, Mr Adams personally left a copy of his calculations with Sir George Airy at the Greenwich Observatory in the autumn of 1845, which fact was rather fortunate as it proved. But, notwithstanding the eminent Bessel bombarded the Astronomer Royal along with others on the same point, nothing was done in the matter of finding the stranger.

On another occasion Mr Adams told me Mons. J. J. Le Verrier had arrived at similar conclusions with himself, and that now Sir George Airy had given directions for a thorough search.

'Would that I had a telescope at command, I would have searched myself,' said he somewhat petulantly. I remarked I thought he had done his part in the laborious calculations.

However, he was to have one now, as he purposed going to Cambridge to assist Professor Challis there.

* * *

ITEM FOR NOTE BOOK.

It is now settled beyond doubt that the moons attending Uranus revolve in the contrary direction to ourselves, our moon, and all other planets, both primary and secondary. How is that?

ITEM FOR NOTE BOOK.

Planet found! 23rd September, 1846.

But oh! the annoyance of the thing! See here a letter from my friend, that I had hardly the patience to read:

ST JOHN'S COLLEGE, CAMBRIDGE,
1st October, 1846.

My dear friend,—Our system has been enriched by another planet, revolving at an immense distance, probably 3,000,000,000 miles from the sun, which will undoubtedly be found to explain all the variations seen in the movements of Herschel's planet. News comes from Berlin, that, acting on instructions from Le Verrier, Dr Galle of that city has discovered it a week ago. Whatever name is given to the disturber will be probably determined by the Frenchman, whom we must not begrudge the honour of being a celestial Columbus. Faithfully yours,

J. C. ADAMS.

P.S.—To be seen at all the new found globe must be a large one.—J.C.A.

Not a word of reproach! Yet had Adams been hardly treated. First in the field—so far as actual hard work was concerned—the honour would have been England's a full year ago, had not Airy blundered, and for that matter, too, Challis as well, for he had instruments quite suitable always at command.

Answering Mr Adams' letter, I applied myself to the words left out rather than to his letter, expressing the hope that in due course his work would be properly appreciated, and reminding him that the papers left with the Astronomer Royal would prove his priority.

As it turned out there was a little storm over the matter; Sir John Herschel and others contending

strongly for equal honours, especially as Challis had noted the planet in the month of August, as was shewn by his papers, but he went on comparing and measuring until too late. The matter ended by the acknowledgment of Adams and Le Verrier as joint discoverers.

ITEM FOR NOTE BOOK.

Neptune the new planet is 38,000 miles in diameter, being rather larger than Uranus; has one satellite and is 2,745,000,000 miles from the sun, and occupies 164 years in completing one journey. *Note.*—Inasmuch as his distance is not twice that of Uranus he fails to comply with Bode's law. So another opportunity for enquiry arises. If other planets are destined to be found perhaps the distance will further diminish, and maybe we shall find a reason why the moons of Uranus move in a retrogade direction.

I cannot refrain from saying that this discovery of a planet from calculation alone is altogether unique, and in my opinion eclipses all other finds in the whole history of astronomy or of any other science.

Before closing note book let me record that Neptune weighs about twenty times as much as our own earth. At this great distance how do I know that?

I have said there is an attendant moon whose distance is shown to be about the same as ours, but she moves round Neptune with four and a half times the speed of ours. If Neptune were not heavier than the earth he could not retain the moon under his influence with such a velocity, for she would break bounds and never return. The relation between velocity in orbit and force of gravitation is as nicely balanced as is a delicate scale for the weighing of diamonds, and we have only to multiply $4\frac{1}{2}$ times by $4\frac{1}{2} = 20$ to know the quantity of Neptune's mass. The mass of Neptune being twenty times the earth's mass, Neptune's satellite *must* move four and a half times quicker than our moon, or the mass would overcome the velocity and the moon

would fall to its primary, with which it would become incorporated in the impact, amid a scene of terrible destruction.

In considering the subject of universal gravitation, I conceive that every body has a determination to the body next it that is bigger than itself—not merely a tendency towards it, but an actual falling (as from a height) in its direction; so that satellite would fall to primary and primary to sun, and the suns—that is the stars—to one another, to a fatal cataclysm of oneness in destruction.

But universal motion is the counterpoise, and since all is in motion, we find the smaller bodies revolving around the larger, not indeed in circles exactly, but in elliptical orbits, subject to perturbation and fluctuating accordingly, disturbing and being disturbed, but always completing the entire journey in the prescribed time.

The problem of contrary forces exactly adjusted, ensuring stability in mutation, is presented to us as propounded and answered before our eyes. The Divine Architect has perfected His work—we observe the facts and straightway call them LAWS!

CHAPTER XVII

CONCERNING THE PLURALITY OF WORLDS, AND THE NEBULAR HYPOTHESIS

ABOUT this time a great deal of interest was aroused in the question of the habitability of other spheres than our own, or the 'Plurality of Worlds' as it was called. A somewhat remarkable essay with the above words for its title appeared without the author's name thereon and the writer's opponents in their onslaughts combated an unknown essayist.

The book was couched in a devout style; the

reverence shown to the Divine Creator being maintained throughout.

He commenced with the well-known expression of the Hebrew psalmist, 'What is Man?', but instead of urging this query in the sense of his littleness and as an argument that other, perhaps far more advanced creatures were probable and indeed likely, he proceeded to adduce reasons why man was the most august being in all the worlds of space. And our globe the *only world* in the solar system in point of fact. He described the large planets as merely vast globes of vapour and water, and the smaller ones as scorched and waterless, and as for the little planetoids, it was equally likely that instead of being a disrupted planet, as many think, that they were bits of planets which had 'failed in the making'.

His main argument was that in the matter of actual density our earth stands first; that it is alone favourably situated as regards light and heat; and that the satellites of the distant planets serve a good purpose independent of their relationship to their primaries, in that they serve purposes of navigation to our seamen.

From a religious view of the matter he calls our attention to the fact that the earth is a scene of moral trial; that man has a conscience and is subject to divine government—a creature that can so far sympathize with the Creator as to raise his intellect into some accordance with the Creative Intellect, and can aspire to live eternally in His presence. In fine, he considers that this is a far nobler thing than any number of brute creations such as he considers possibly to exist in some other globes in our system.

With much of this we feel, instinctively, to be in accord, as we are carried away by his impressive reasoning; but how shall we as easily agree when he tells us that of the countless myriads of stars probably none of them are so adapted as our sun to control and support a retinue of planets, which bodies, even in our solar system, he reduces to but one that is a tenantable globe? He even suggests that probably

the stars are not even actually consolidated suns, but immense patches of luminous vapour, and seeing that they are *points* only, and would be but points if thousands of times larger than our sun, so they may be nebulous and unfitted as centres of life and intelligent thought. To which we can only reply for want of knowledge — Perhaps! and perhaps not.

WE think ourselves wise, but our wisdom must be very foolishness to the Almighty One.

In a very short time the subject was hotly debated, the great majority of critics being dead against the essayist; Chalmers, Andrew Fuller, and S. Noble entering the lists, and the Rev. Mr Nares attempted to show that our Redeemer's death might avail in other worlds equally with ours.

Sir David Brewster was specially asked to examine the question, which resulted in a book entitled *More Worlds than One.* Caustic throughout, and, at times, perhaps extravagant, as when he suggests for worlds far distant from the centre of light and heat, that subterranean cities warmed by internal fires may be used by rational beings, as such dwellings are used by creatures of instinct only in ours. Apart from this, his criticism was a very forceful one, and the main objection to the essayist put forward was this: that it was derogatory to the Majesty of an Omnipotent Creator to minimize his power as well as his goodness in seeking proofs that out of millions of shining orbs, many manifestly more resplendent than ours, that our earth-world, constituted the *summum bonum* of the whole! And to my humble judgment that appeared sufficient.

A friend of mine asked the essayist (through the Press) 'Did he think that all the stars which we see in the vault of heaven on a fine winter's night are either made for nothing, or made to give a scanty gleam of light to the earth?'

If we let imagination wander, into what unfathomable mazes may we not enter! It is admitted that myriads of millions of years may have elapsed since the world began, and yet the history of our race is

barely 6,000 years old. What about the preceding years, or ages? Did the angels inhabit the earth in a pre-existent state? Who can deny the possibility? Again, did the angels that fell pass their time of probation here? Why not? Who can tell? We should look in vain for remains of tenants who had been transported to worlds of bliss or woe.

There is more in heaven and earth than our philosophy can probe, and the very thought that gives birth to suggestions such as these, instinctively cries, HALT!

In conclusion, the whole controversy appears to illustrate the point: how difficult it is to prove anything outside our ken, and also how easy, apparently, to prove anything *pro* or *con,* as we may desire, by special pleading. This particular instance, contemplative and academic, reminding us of the age of the school-men rather than of the philosopher.

* * *

Eternity is a mystery; endless space is an equal mystery! It is as difficult to imagine the confines of space as to imagine its infinity. The existence of matter and its production is altogether beyond our comprehension. The popular notion is that the Divine First Cause spake the word and things were; and argue as we will, we cannot improve to our unbiassed satisfaction. All things appear to us the result of natural causes, but the origin still evades us.

Did the Omnipotent One shape the worlds as they appear, and launch them on their respective paths?

La Place has startled the world with his

Nebular Hypothesis.

It is natural, certainly, to maintain that alterations in the constitution of matter have from time to time happened. The earth is hot internally—very hot.

The inference is it was once hot at the surface as well, nay, even in a state of vapour, and consequently vastly greater in size than now. Again, since it was once hotter and is now cooling, we may decide that it will become colder and even cold. How many millions of ages this will take is beside the question.

La Place argues that once upon a time the solar system was *one* mass of luminous vapour—vaporous gas—and that in process of time a quick rotation resulted in the outlying portions becoming detached in the form of an independent ring, analogous to what we see around Saturn, and that this detached ring eventually closed up in a resultant planet; the process is continuous, and one by one the various planets are produced, the centre of the whole becoming more dense producing our illuminating sun.

The idea obtains some support from the fact that the motions of the planets are in the same direction, as well as travelling nearly in the same plane, and that the satellites move in the same direction as their primaries (how about the moons of Uranus), and it is supposed that the satellites result from subsidiary rings.

The hypothesis has 'caught on' and many of the most distinguished astronomers give it their adhesion.

It is within our province to search for adequate causes, and the reflective mind will allow that the Creator would presumably perform his wonders in the simplest manner. It should offer the devout no sort of hindrance in the matter of faith.

But there is always a for and against in any hypothesis, and although what La Place suggested as the genesis of our system seems very plausible, there are one or two considerations that call for attention. It might be surmised, for example, that in a whirling system of gas, where every particle, infinitely small, has its identity and individual atomness, that the inner portion would be most dense and the outer most rare, which qualification would become more pronounced as the ages wore on; yet

would the outer portion move much more slowly than the inner at the same time. We find that the outer planets do move much more slowly than the inner. But there is this significant divergence: the rings of Saturn move faster than their primary inside them. Again, the moons of Mars (recently found) move much more rapidly than does Mars within them; and the same remark applies to one satellite of Saturn's. Whence came the energy to impel the satellites by the planets—faster than themselves—if the central sun failed to impel the planets quicker than himself? And while much in fairness must be conceded La Place, I submit my points are serious flaws to the idea. Again, since all the planets travel within a small margin in the same plane as might be expected, as being deported from the equator of the central mass, how comes it that the ecliptic and the equator disagree in our earth and in the case of the other planets? Would not one and the same cause produce an equable motion?

I would also expect that in a whirling agglomeration of gases, far extending beyond Neptune's orbit, and infinitely rare, that the outermost portion would be dissipated, at any rate, as to the more volatile constituents, much more likely than they should coalesce and become independent globes.

Who shall decide between the two schools, one contending for the natural evolution from gaseous oneness, the other for a creative act?

Or who will doubt the need of a first cause for either origin?

CHAPTER XVIII

A DISSERTATION ON TIME

FROM speculations of eternity let us revert to matters of time.

What is TIME? It is a conventional term—and a comparative one. Eternity is not time; but time is a portion of eternity, as a chip may be a portion of a block. We have here to consider what to us is the effect of diurnal and annual revolution. We say $365\frac{1}{4}$ revolutions of our earth on its axis is one year, because in those $365\frac{1}{4}$ revolutions it has also travelled once round the sun, and each revolution round its own axis we call one day. The effect of diurnal revolution is to cause the presentation of every part of the globe to the sun in succession, giving us our morning, noon, evening and night. So also annual revolution gives us spring, summer, autumn and winter.

It is fortunate for us that all motion is uniform; for although I may have to mention several divergences from the above statement, yet those very divergences are uniform and easily understandable, and we obtain our measure of time accordingly. An apparent anomaly will be patent to every careful observer and needs explication.

Our daily revolution is effected in twenty-three hours, fifty-six minutes, four seconds. Suppose now we fix our telescope to note when any star—say Arcturus—passes our meridian. It may be, say, eight P.M. to an instant. On the next night we watch as closely, and we find that the star passes at seven hours, fifty-six minutes, four seconds, that is three minutes, fifty-six seconds *before* eight o'clock.

Have we made a mistake; that is, is our clock at fault? The next night the same thing occurs, the star is now twice three minutes, fifty-six seconds earlier, and crosses the meridian at seven hours, fifty-two minutes, eight seconds. We ascertain, in fact, from this phenomenon the exact time of our one revolution. But it is not the measure of our day. If we watch the sun on two successive days we find the moment of noon, or greatest elevation, to be twelve o'clock. Therefore, our clock is not wrong; there is a disparity between star and sun, and this is the reason. The earth has a compound motion; first, round itself, secondly, round the sun, which journey is performed in three hundred and sixty-five days, five hours, forty-eight minutes, forty-nine and a half seconds. You must now understand that each time the earth turns round it must also have travelled a 365th part of its annual journey round the sun, and consequently must needs perform a 365th part of another revolution before any one meridian (or one point on her surface) is face to face with the sun again. With the stars it is different: one exact revolution of the earth brings us face to face with any one star. If then we require a 365th more than one revolution to face the sun it follows that in 365 days we have gained one whole day (star-day) in 365 fragments of three minutes and fifty-six seconds. In plain terms, while the sun appears to rise and pass the meridian 365 times in making our year, the star has passed 366 times in the same interval.

This explains why the sun appears to lose ground, so to speak, with the stars, and in one year pass through all the constellations of the Zodiac. The earth revolves in twenty-three hours, fifty-six minutes, four seconds, but we get our twenty-four hour day by adding the three minutes, fifty-six seconds, as the nature of our compound motion requires.

There is, however, a further adjustment required to meet our commercial and day-to-day needs, for, in itself, the day is not quite invariable. We have only

to remember that the earth's orbit is elliptical, and that when nearest the sun we travel a little faster, and when farthest from the sun a little slower than our mean rate. So astronomers have invented an imaginary or fictitious sun, which is supposed to move regularly; hence we have three rates — the sidereal, the solar and the mean. The solar and the fictitious suns are sometimes fifteen minutes in disagreement, but on four days in the year, namely, at the two solstices and the two equinoxes, they are in agreement.

As the year is longer by nearly six hours than 365 days, it was discovered that the years were getting a little out of season as time went on, so now we have an addition of one day in four years, which nearly keeps the matter right—hence our leap year. This one day in four years is, however, rather too large an allowance, so it is occasionally dispensed with—1700, 1800 and 1900, which should be leap years, were decreed to be ordinary years. By this arrangement the length of the commercial or mean year never differs by so much as one single day from the solar or tropical year.

A word or two about our sub-divisions of time. We divide our day into 24 portions and call them hours. We might have decided on 360 minutes as there are 360 degrees to our circles. In some respects this would have been convenient, as I will show when dealing with longitude, for in that case a minute of time and a degree of longitude would have been commensurate. But since twenty-four hours are decided on, shall they be 24 parts of the sidereal day, in which case the sun would be reckoned as going slow; or as in fact 24 parts of the mean sun which makes the stars go fast. You will see that either might do, as in both cases an equation would be necessary. Evidently much thought and trouble awaits the astronomer at every successive point in the acquisition of knowledge. I remarked just now that time was a conventional—a comparative term. Time, as we have it, is known nowhere else in the universe. A day with the Lord is 1,000 years;

or shall we say 1,000,000? — Nay, that even is altogether too short!

From what I have said it must be obvious that each planet has its own time—there is no common time.

We know that in 1066 the Battle of Hastings was fought; in 1866 the Battle of Sadowa was fought, a lapse of 800 years intervening. A denizen of Jupiter able to read earth-history would say that only 66 years had passed, for supposing exactly 12 of our years for one of his journeys round the sun, and dividing 800 by 12 we have the answer. A Uranian would say only 10 years had passed, for

$$800 \div 82 = 10 \text{ nearly.}$$

If it be our estimate of life—its length, its wear and tear, its expectations, all depend on that portion of eternity represented by a complete circuit of the annual orbit, and not the number of days only, then a Jovian now living would be in about his prime, though he first saw the light when William the Conqueror landed on our shores. And in the same time a Uranian would still be in childhood. I speak thus to show that time as we have it has nothing in common with any other spot in the whole creation.

* * *

Time, then, is a record of a planet's revolutions. The regularity of all these movements is absolute. The revolution on the axis is performed to a second, the *nodding*[1] in obedience to the moon's attraction on the extra mass at the equator, to the exactness of scales in the weighing of diamonds; the divergences of path because of a neighbouring planet's influence precisely in accordance with nearness and mass; and as Mitchell finely says:

'Should the rotation of the earth be increased by five seconds in twenty-four hours all the time-keepers in all the watch houses of the world would

[1] See Glossary.

proclaim the fact: all the stars would fail to keep their appointed meridian transits, and would, in sympathy with the great orbs of heaven, linger in their nocturnal march. The bursting out in the heavens of a thousand fiery comets in a single night could produce no such mortal terror to the astronomer as this falling backward of the mighty sphere of the starry universe for one single second in twenty-four hours, *for it would proclaim the doom of the universe*, in announcing that God's right arm was growing heavy — the astronomer would stand aghast, for no remedy could avail to rectify the wrong!'

CHAPTER XIX

LONGITUDE, LATITUDE, THE *NAUTICAL ALMANAC*, THE MOTION OF LIGHT, ETC.

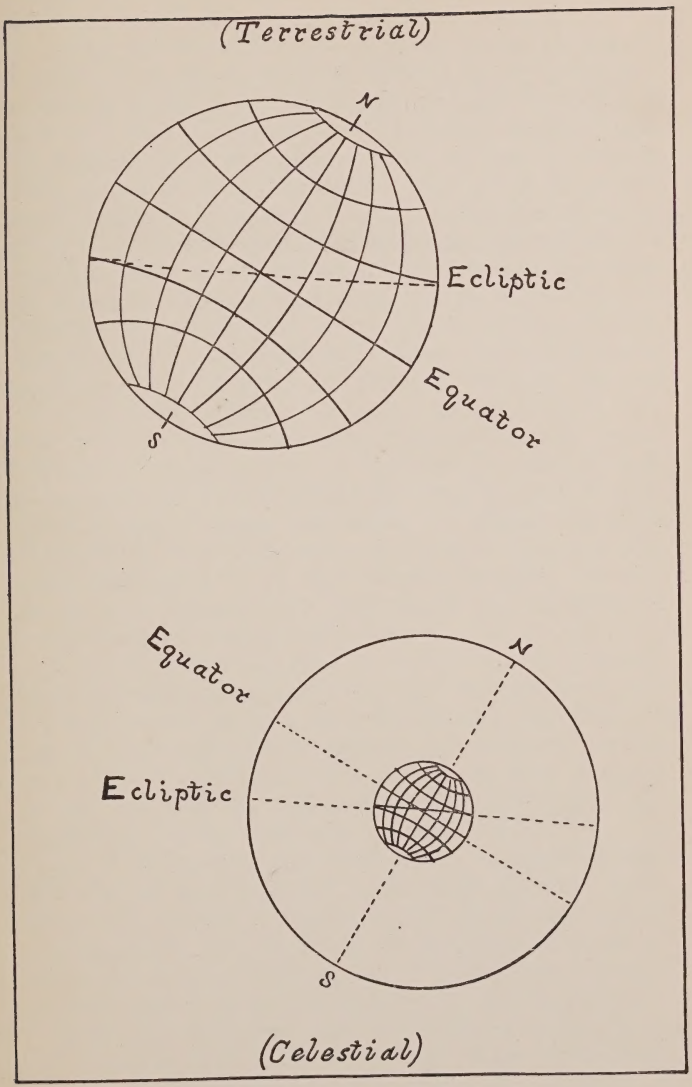
We have now to consider LONGITUDE, and in its connection several other terms, as Latitude, North Polar Distance (N.P.D.), and how by their means we may determine any place upon earth that may be unknown to us. This is of special interest in navigation, as, until these means were understood, seamen had to cling close by a coast-line, or venture across but very short reaches of open sea. Second in importance only to this was the later discovery of the mariner's compass and the magnetic needle, which in all weathers (though no single star be visible) indicates the north and hence gives *direction*, but not location. This, however, is outside my subject.

Astronomers and geographers adopt the same method of dividing the earth and the visible universe, by imaginary lines for longitude and latitude. The terrestrial equator dividing the earth equidistantly

between the poles. This same great circle produced infinitely divides the visible universe likewise. Counting the equator as 0 we have 90 degrees to the North Pole and 90 degrees to the South Pole; 180 degrees from pole to pole. These are degrees of latitude. Longitude is measured similarly by great circles cutting the poles. In this country Greenwich is chosen for the 0 position, the exact point being where the spider lines intersect in our great national transit instrument. From that point degrees are measured east or west as the case may be. All this will be quite understandable to those acquainted with maps and globes representing the earth.

Now let us suppose a globe representing the earth, and a very much larger one enclosing it—the earth-globe being central. It is easy to suppose all the earth lines of latitude and longitude extended so as to divide the outer sphere in exact likeness. This is what astronomers do. On the outer sphere we suppose a faithful representation of the stars; we look upon them in the reverse order, but from the centre they would appear as on the sky. The pole-star will be opposite the North Pole of the earth-globe, and all the other stars in their relative places. If a turning movement from west to east be imparted to the earth-globe, the outer sphere would appear, although at rest, to pass from east to west, and all the phenomena of the heavens be produced in miniature. If the latitude of Greenwich is 51° 30′, it follows that its distance from the North Pole is the complement of 90°, or 28° 30′, and if we observe a star that is 28° 30′ from the North Pole of the heavens, that star must always be absolutely in the zenith or directly overhead when passing Greenwich. Such a star is Draco.

Now for the application. If we observe a star as directly overhead (to us, where we may happen to be) and we find that star to be, say, 10 degrees nearer the pole, we know from that observation we are 10 degrees north of Greenwich — somewhere. Where that somewhere is we must determine by finding the


(Terrestrial)
N
Ecliptic
Equator
S
Equator
N
Ecliptic
S
(Celestial)

longitude. In its main factors, and that is all I am concerned with, it is easy of explanation.

A day divided into 24 parts gives us our 24 hours; a great circle of 360 degrees, divided by 24, gives 15; therefore 15 degrees of longitude are equal to one hour of time. If a star is known on a certain day to reach its highest point at Greenwich at 10 P.M., I observe that star and note the local time when it passes *my* meridian. Suppose it is 9 P.M., I shall therefore be situate 15 degrees east of Greenwich, because, as the star has reached the meridian one hour earlier than it is due at Greenwich, the earth has manifestly to observe one 24th part of its daily motion before Greenwich can be under that same star. My exact position then will be in Hellsingland, in Central Sweden, because the 15 degrees east longitude and $61\frac{1}{2}$ degrees north latitude intersect at that point. Similarly, suppose when I observe the star (due at Greenwich at 10 P.M.) the local time is 11 o'clock, it follows that I must be situate 15 degrees *west* of Greenwich, and supposing the same latitude, the place indicated is in the North Atlantic, not far south of Iceland, and my place of observation necessarily on board some vessel.

It is not always as easy to reckon on the celestial sphere from the equator to get our latitude, but we may resort to another method—we can find the north polar point, elevated, say, $13\frac{1}{2}°$, we then measure to the point overhead—the zenith. If that distance is 15° we will, by subtracting 15° and $13\frac{1}{2}° = 28\frac{1}{2}°$ from 90°, get our latitude, namely $61\frac{1}{2}°$.

As I remarked, did our hours measure fifteen minutes of two hundred and forty seconds each, then one minute of time would equal one degree of longitude. As it is, in every *four* minutes of sixty seconds, one degree (or 360th of the celestial sphere) passes over any one point on the earth.

It is clearly quite easy by sub-dividing hours and minutes into seconds, and by using instruments of good construction to determine the position of any place to a nicety.

* * *

To understand to what degree of exactness our astronomers have attained, one need only to know that the moment of an eclipse, an occultation, a conjunction, or an opposition can be, and is predicted years in advance. A book called *The Nautical Almanac* is published under government control, in which is detailed the positions of the planets and the moon with respect to each other for every three hours in the year, by means of which one's whereabouts and the exact time can be readily ascertained, provided one has the exact Greenwich time also; this being effected by having a chronometer previously timed to agree with Greenwich.

It also states when the eclipses of Jupiter's moons take place—and here I may properly explain the particulars of this phenomena.

A strong light will always cast a shadow behind any opposing dark body. When the moon enters the shadow of our earth, cast behind us by the sun, the moon sustains an eclipse. Now the sun causes a dark shadow to fall behind Jupiter in exactly the same way, and the encircling satellites may be seen with the aid of a telescope entering and emerging this shadow, and tables have been constructed predicting the exact times both of ingress and egress as I have intimated.

Here then exists a ready means of getting the time when these observations can be made.

To show how one fact ascertained oftentimes leads to others, let me note here the discovery of the *velocity of light*. It might perhaps be thought that light was instantaneous, but it has been shown by Roemer, a Dane, that light travels at the rate of about 186,000 miles per second. If a star suddenly appeared, therefore, having no sensible parallax—proving its immense distance—we should know that it must have been in its position, although only just become visible and apparently *new*, for at least three to four years; for its light, travelling at nearly 200,000 miles per second, would take that time in traversing the distance before it could suddenly blaze forth to our vision. Further,

were a star to suddenly *disappear* it would be telling us that at least so many years previously had some catastrophe happened, for the light leaving the star would continue on its way at the above rate, notwithstanding the extinction of the source of the light. This is also referred to as the *progressive motion* of light.

But to explain :

Roemer found that when Jupiter and the earth were in conjunction, that is on the same side of the sun, the tables prepared were found to be quite correct, but when Jupiter and the earth were on opposite sides of the sun, the entry of the satellite into the shadow and its subsequent emersion occurred sixteen minutes after the calculated time. The conclusion he deduced being, that since the distance apart of the two globes differed in the two situations by the whole measure of the earth's orbit, the sixteen minutes is occupied by light in traversing that distance of 182,000,000 miles, from which the rate per second can easily be calculated.

Hence it must require eight minutes for light to reach us from the sun, which is central in our orbit. Hence, also, we can never see the sun where he *is*, but where he *was*, eight minutes previously. To show how great a displacement there is, direct a telescope to the sun and wait eight minutes; in most instruments he will have disappeared from the field of view altogether.

Let me warn you, however, never to look at the sun without a proper sun-cap of darkened glass, or permanent injury to the eyes is almost certain.

CHAPTER XX

A FEW WORDS ON VELOCITY—QUICK AND SLOW

How quiet and still is nature to an observer seated, say, on a grassy slope, with the sun sinking in the west—mayhap the harvest moon just peering through the haze of the eastern horizon. The noisy songsters of the morning are now seeking repose, and the myriads of gnats and flies disporting in the cooling air, alone give indication of movement—their ceaseless gyrations spelling pleasure and content.

How difficult is it in such calmness to apprehend the truth that we are rapidly whirling through space! Yonder aspen leaf quivering in the lightest zephyr; its shadow delicately limned on the adjacent background, dancing in company therewith, speak to us of cause and effect that is easily understandable, but where is there any evidence of our own motion?

The sun meanwhile has nearly disappeared, and we can sympathize with the old-time watcher as he feared for its return! 'Will the night now coming ever pass and we behold his face again?'

Oh yes! it is evident to our senses that the sun ceaselessly travels around our habitation.

But notwithstanding appearances, we now know that it is we and not the sun that is moving. The balloonist in his aerial flight sustains no sense of motion except that the earth recedes from him, and on his descending, the earth, in contrary fashion, appears to meet him—so we ourselves feel no movement, no jar, because our motion is equable, and because the atmosphere surrounding us partakes of the motion also.

Let us now note the compound motion we take part in, and measure it.

By observing the stars we find that the earth turns round itself once in twenty-three hours fifty-six minutes. Situate on the equator, where the move-

ment is most rapid, one would be carried through 25,000 miles in a little less than twenty-four hours, or more than 1,000 miles an hour, and yet there is no movement observable.

The actual motion would become less rapid as one receded from the equator, and could we stand absolutely at either pole, the only motion experienced would be a daily turn round ourselves, as if standing on a slowly moving turn-table.

The maximum movement, therefore, is about 1,000 miles per hour.

We also partake of an annual turning round the sun, from which we are distant 92,000,000 miles. The diameter of our orbit is therefore twice that or 184,000,000 miles. Multiply that figure by 3.14 to get the circuit, and we find we travel in one year

574,310,000 miles.

Dividing by $365\frac{1}{4}$ and by 24, we learn our motion per hour to be

65,518 miles,

or no less than *eighteen* miles in every second of time.

A third motion is that of the whole solar system in space, a movement that we, in common with the sun and the planets, take part in, and which reaches approximately 50 miles per second, or 180,000 miles per hour.

To summarize:—

The Axial motion	per hour	.	1,000 miles
The Annual „	„	.	65,518 „
The Solar „	„	.	180,000 „
The total movement	„	.	246,518 miles.

A greater distance than from the earth to the moon!

It is difficult to conceive a speed such as this in the absence of all sensation of motion.

There are other movements our earth is subject to I will now refer to: one, sometimes called *nodding*, but more scientifically, *precession* and *nutation*; and another one, the motion in conjunction with our moon round our common centre of gravity (c.g.).

To understand the first of these two, call to mind the fact that all matter attracts all other matter, which is the core of the law of universal gravitation, and that the earth is not exactly round. It is a 299th larger, measuring at the equator, through the earth, than from pole to pole through the earth; the protuberant excess at the equator being the natural result of our daily rotation, whilst the earth was in a plastic condition.

Now what is this protuberance but more matter—more to be acted upon by the attractive force residing in sun and moon. If these bodies were directly opposite the equator, no effect would result, but as the earth is tilted, whilst journeying, the sun and moon are sometimes above and at other times below the equator, appearing in fact in what is known as the *ecliptic* or apparent path of the sun.

We have now got to the cause, for when either body is north of the equator it pulls the protuberant matter as if it were a handle, and so depresses the pole to a like extent; when south of the equator it pulls the opposite way and consequently raises the pole.

The sun hinders the equable motion of the earth by this pulling to a certain, though very minute extent (50″ annually); the earth twists, as it were, in its journey, and the effect is that a different point of the heavens is opposite the pole of the earth continually, our polar star will one day give place to another one and later to another, and in 25,868 years our present pole star will be back in its same position once again. As all the constellations move in unison the point where the ecliptic and the equator cross each other varies at the same rate, and this is called precession, or, the passing of the equinoxes.

The moon's action is more decided and quicker as she—though so small—is much nearer than the

NEW
First Quarter
FULL
Last Quarter
NEW
First Quarter
FULL
Last Quarter

sun, and moves so much more quickly. The result in this case is called *nutation.*

I mentioned just now the matter of the centre of gravity. Is the earth travelling round the moon, or the moon round the earth? The answer is that neither one nor the other, precisely so, although in a measure they both do. In order this may not remain a parodox let us consider:

The earth is eighty-one times heavier than the moon. Now suppose we try to balance them by a feat of imagination. In the adjoining plate I have represented two globes—the earth globe and the moon globe—connected with a rigid rod. Now where shall we place the edge whereon they may be poised? Clearly not in the centre. Even as in the second figure the earth would far outweigh the moon. We should have to make a notch in the earth globe itself for the fulcrum edge before the two globes would balance. The figure also shows such a method. This point—where the notch is made—about $\frac{1}{5}$th way inwards in the earth's own body, is the centre of gravity of the two globes. *This point* it is that travels round the path of the earth's orbit. It follows, therefore, that the earth assumes the positions portrayed in the figures at different times in the lunar month.

It is interesting to consider, as a consequence of the law of universal gravitation, that were all the planets moulded into one globe, and we sought the centre of gravity of sun and planet, we should find it well within the sun's own body.

I shall have effected my purpose in bringing all these matters before you, if you will form some idea of the difficulties that await an astronomer in his work. There are, however, many others, notably: *aberration* and *refraction*, which I will explain later.

Before leaving this branch of the subject, namely, great velocity, it may ease the mind, perhaps, to consider relatively *slow velocity*; for velocity really means rate of motion, and not necessarily great speed.

I have said the earth travels 65,000 miles per hour, or, 18 miles in every second; but what is that

considering her bulk and diameter? At 18 miles per second it would take her nearly eight minutes to travel a distance equal to her own diameter. Jupiter moves more majestically still, for his diameter is 86,000 miles; but, since he travels but 27,000 miles in an hour, there must needs elapse a period of three of our hours before he travels a distance equal to his diameter!

A cricket ball emulating the speed of Jupiter would occupy no less than 528 hours in its passage from bowler to batsman. Verily there is a leisurely grandeur in the movements of the heavenly bodies!

CHAPTER XXI

A BUDGET OF ODDMENTS AND A VOTE OF THANKS

A MEETING of our Society was held last evening of an unusual and interesting variety. The more prominent members had been deputed to speak as for one eminent astronomer, each presenting in a few words some idea or statement peculiar to the authority selected. For simplicity, I will name the authority instead of the member.

Being in the chair, I opened the ball with a remark of R. A. PROCTOR:

'The principal charm of astronomy, as indeed of all observational science, lies in the study of CHANGE —progress, development and decay—and specially of systematic variations taking place in regularly recurring cycles.'

Professor S. NEWCOMBE:

'Supposing the mass of the sun to be divided into 1,000,000,000 parts, we may be the better able to compare the relative sizes of the planets separately

and combined with respect to the solar mass; 200 of such parts being apportioned to Mercury. A curious feature, too, in the sizes of the planets will become apparent, viz.: that every planet that is next largest contains more matter than the combined mass of all the smaller ones. Thus:

Mercury	200	parts
Mars (the next largest) .	339	„
Combined . .	539	„
Venus (third largest) . .	2,353	„
Combined . .	2,892	„
Earth—and moon—(fourth largest), ...	3,060	„
Combined . .	5,952	„
Uranus (fifth largest) . .	44,250	„
Combined . .	50,202	„
Neptune (sixth largest) .	51,600	„
Combined . .	101,802	„
Saturn (seventh largest) .	285,580	
Combined . .	387,382	„
Jupiter (eighth largest) .	954,305	„
Total combined mass	1,341,687	„

'So it appears that the whole mass of all the planets is one and a third million parts as against ONE THOUSAND MILLION parts residing in the sun.'

Doctor DICK:

'Considering our position in the ordinance of nature—the third planet in order from the sun—let us view the earth a little in that character. Generally called round, it has been proved to have

a shape somewhat different to a perfect sphere, and is properly described as an *oblate spheroid*, having a polar diameter of 298 parts only, as against an equatorial diameter of 299 parts; that is, the polar diameter is the shorter by $\frac{1}{299}$th. One proof of this has come through the pendulum. M. Richer, a Frenchman, in a voyage made to Cayenne, which lies near the equator, found that the pendulum of his clock no longer made its vibrations so frequently as in the latitude of Paris, and that it was absolutely necessary to shorten it in order to make it agree with the times of the stars passing the meridian. Some years after this, Messrs Deshayes and Varin, who were sent by the French King to make certain astronomical observations near the equator, found that the pendulum at Cayenne made 148 vibrations less in a day than in Paris, and that his clock was retarded, by that means, two minutes twenty-eight seconds; and was obliged to make his pendulum shorter by two lines, or the sixth part of a Paris inch, in order to make the time agree with that deduced by celestial observations. Sir Isaac Newton and Mr Huggins were among the first who perceived the extensive application of this discovery, and Newton's penetrating eye tracing the fact through all its bearings determined the true figure of the earth, as Fontenelle remarked, "without quitting his elbow chair." From a comparison of the length of different degrees of the meridian lately measured, the equatorial diameter is about 7,934 miles, and the polar 7,908 — the difference being 26 miles. From the circumstance here noted, we may learn that the most minute facts connected with the system of nature ought to be carefully observed, investigated and recorded, as they may lead to important conclusions, which, at first sight, we may be unable to trace or to appreciate—even the beating of a pendulum.

'To an inhabitant of the moon, our earth would appear most resplendent. It would present the appearance of a globe in the sky *thirteen times larger* than the moon does to us. As the moon always

presents nearly the same side to our view, so the earth will be visible to only one-half of its inhabitants.[1] When the moon is *full* to us, we will be new to them, when the moon is *new* to us, we will appear *full* to lunarians. When a total eclipse of the *moon* happens to us, there will be a total eclipse of the *sun* to them, which would last nearly two hours, whereas, she can only eclipse (totally) the sun to us for about four minutes. The earth would appear to them always resident in one position so that distant inhabitants would need have to journey to obtain a view. Indeed the study of astronomy would be much more difficult for them; they would see all the heavenly bodies revolving round them, the earth alone stationary, and might naturally suppose their own globe (and ours) the only quiescent states in the Universe.

'Although Jupiter and his moons might always be in ignorance of us, let me say, in passing, that Jupiter would appear to a person on his nearest satellite no less than *thirteen hundred times* larger than the apparent size of our moon, and would occupy a considerable portion of the celestial hemisphere. The expansive and variegated surface of Jupiter, its diurnal rotation, and its rapid changes of phases would therefore form a most wonderful and interesting spectacle to the inhabitants of this satellite.'

J. Norman Lockyer:

'What are some of the benign influences spread broadcast by the sun? First, *Light.* Can we gauge its intrinsiç brightness? It is clear at once we cannot express it in candle power, let us therefore compare it with one of the brightest lights that we know of, the lime-light. The lime-light proceeds from a ball of lime made intensely hot by a flame composed of a mixture of hydrogen and oxygen playing on it. It is so bright that we cannot look on it any more than we can look on the sun; but

[1] Always supposing it has any.

if we place it in front of the sun and look at both through a dark glass, the lime-light, though so intensely bright, looks like a black spot. In fact, Sir John Herschel has found that the sun gives out as much light as 146 lime-lights would do if each ball of lime were as large as the sun and gave out light from all parts of its surface.

'There is something else besides light (and heat) in the sun's rays, and to this something we owe the fact that the earth is clad with verdure; a force is it—*a chemical force*, which separates carbon from oxygen, and turns the gas, which were it to accumulate, would kill all men and animals, into the life of plants. *Thus then*, does the sun build up the vegetable world.

'Enormous engines do the heavy work of the world; locomotives take us smoothly and rapidly across a whole continent, mail packets take us safely across the broad ocean: owing all their power to steam, and steam is produced by heating water by coal. Now let us think a little. We all know that coal is the remains of an ancient vegetation; we have just seen that vegetation is the direct effect of the sun's action. Hence, without the sun's action, in former times we should have had no coal. The heavy work of the world, therefore, is indirectly *done by the sun.* Man himself — be he prince or peasant—is but a little engine, which *directs* merely the energy supplied by the sun.'

RICHARD A. PROCTOR:

'It is difficult when we look at the star-lit heavens, suggestive as they are of solemn peace, to conceive the stupendous energy, the fierce uproar and tumult, of which even the faintest visible star in reality tells us. But while our powers of vision are limited to the narrow range of our present telescopes, we cannot watch the action of these great centres of energy. nor can we hope that the uproar of those remote fires will ever reach mortal ears, though to the mind's eye clear and distinct. We know that in each star

processes resembling in violence those taking place in our own sun must be continually in progress, and that such processes must be accompanied by a noise and tumult compared with which all the forms of uproar known upon earth are as absolute silence. The crash of the thunderbolt, the bellowing of the volcano, the awful groaning of the earthquake, the roar of the hurricane, any of these, or all of them combined, are as nothing compared with the tumult raging over every square mile, every square yard of the surface of each one among the stars!

'There have been *new* stars, so called, that have suddenly appeared and in a few years as completely vanished. There are variable stars. Astronomers recognize our sun as in one sense a variable star, for we can hardly suppose he shines with the same degree of brilliancy when many spots mark his surface, as when quite free from spots—these changes in the sun's condition correspond to wonderful changes in his activity. When a new star suddenly blazes out as in the *Northern Crown* in 1866 spectroscopists saw a rainbow-tinted streak crossed by a number of dark lines. But besides these there were seen four very bright lines,—lines so bright that the rainbow-tinted streak appeared as a black background. This signified that besides the vapours which, being cooler than the star, absorbed a portion of its light and produced the dark lines, some vapours were present in the star's atmosphere which were a great deal hotter than the star and so produced the bright lines.

'The general belief was that there had been a downfall of matter on the star, by which the whole globe of that sun had been excited to an intense degree of heat, especially at the surface, near which lies the hydrogen atmosphere of the star. Certain it is that if our sun ever undergoes a baptism of fire which has effected some few among his brother suns, our earth and her companion worlds would for ever remain absolutely devoid of life. Unless, indeed, spontaneous development of life, which

Science knows nothing about, or a new creation peopled the earth afresh.

'The Greeks undoubtedly, as also the ancient Egyptians, believed the world to be subject to occasional conflagrations and deluges, whereby the Gods arrested the career of human wickedness and purified the earth from guilt. And the Abbe Moigno believed it was an event of this sort that St Peter predicted when he wrote that as the old world, being overflowed with water perished, so 'the heavens and earth which now are, by the same word are kept in store, reserved unto fire.'

'There are so many millions of suns, however, in the region of space, that the occurrence of ten or twelve known outbursts in the course of four or five centuries need not be regarded as implying any serious danger.'

Sir ROBERT BALL:

'Shall we ever be able to communicate intelligently with peoples of other planets? Often has the question been asked. Mars is at times most favourably placed —can we direct the Martians' attention to a code signal and elicit a reply? Perhaps! Say we get a giant flagstaff about 500 miles in length and attach thereto a flag about as large, say, as Ireland, find some means of waving the flag—then, should the Martian astronomers be possessed of instruments equal to our own, I fancy I hear them saying "What are they doing down there (or up?); I thought I saw something twinkling!"'

Professor NORDENSKJOLD:

'The earth is growing at the rate of at least 500 tons a year. This is in consequence of the attraction she exerts, drawing to herself countless numbers of small meteorites—ranging from the size of a pea to a cricket ball, but occasionally much larger—that she encounters in her journey round the sun. No doubt all the planets gain in weight in the same way.

Many millions of these tiny wanderers are caught by our atmosphere in a single day; some of them we see as shooting stars. It has even been suggested that Mars obtained his two small moons by attraction; that they are really two of the planetoids that wandered dangerously near, and were forthwith purloined by him. In like manner countless myriads are constantly finding their last home in the larger body of our sun.'

(Bearing out what Mr Proctor surmised as accounting for variations in the heat of the solar mass.)

Other interesting papers and extracts were presented to the meeting, that cannot be detailed here, and then the Rev. THOMAS MARSDEN, B.A., rose to propose a vote. He had, he said, for many years studied the earth as a planet, and was satisfied that it had not always been a *rotating* globe, but had sped its way, probably in a cometic state with the same face always to the sun, at which period the waters had universally covered all its surface. In that state, the granite, which we know to be found in all places, was forming.

It was not necessary for us to determine whether Almighty God caused the rotation by simply bringing it into that position respecting the sun's rays which would by the laws of electro-magnetism produce rotation, or whether He effected it by a more immediate and special active volition. It is enough that He decreed it should be and so it was: 'Let there be gathered together the waters from under the heaven into place one, and shall be seen the dry land; and it was so.'[1] But he threw out the suggestion: The earth was an electro-magnet, with electric currents passing from pole to pole, in circles gyrating from East to West. Long continued observations in almost every part of the world have taught us that electricity circulates round the earth from East to West and that the intensity of its currents is controlled by solar radiation. They increase from dawn to noon, and diminish as night

[1] Literal translation.

advances. The sun, therefore, is the source of electricity as well as light and heat; and as the course of the currents is East and West there is no difficulty in understanding that the magnetic currents *must* be *across*, that is at right angles, or North and South. He conceived that here was a sufficient cause producing rotation—the waters would be gathered at the equator and the dry land would for the first time appear.

Now observe, in his opinion, the equator at the first rotating was such that all parts of the earth were equally presented to the sun, the equator and the ecliptic coinciding, thus favouring the tropical vegetation geology discovers us.

How then was the change to the present position of the equator effected? When, in fact, were the *poles of the earth inverted?*

By what agency this was effected we are not told, but we read Jehovah said: 'I will destroy', and if, as he thought, this change was wrought at the Deluge, all difficulty attending the necessary quantity of water was explained away. The forty days flooding rain was altogether too small, but they indicated the vast magnetic disturbance in the atmosphere, and then the sudden inversion of the earth's axis would necessitate the immediate rushing of the waters of the oceans to the new equator, and it was not possible to conceive with what velocity they would travel. The great deep would be broken up, and for the space of at least 150 days would the waters prevail, rushing in one mighty stream round and round the whole earth carrying the Ark on the equatorial surface of its vast tidal wave. Hence, also, when at length the waters assuaged, sea and land would in many cases have changed places, and to a great extent, the Deluge would have destroyed the earth.

He hoped the friends would pardon the digression—if they thought it such.

He had been particularly pleased with the meeting, and he moved a cordial vote of thanks to the Chairman. (Cheers.)

CHAPTER XXII

AFTER THE BUDGET

THE Rev. Dr CHALMERS rose to second the vote of thanks. 'Infidelity', said he, 'often had recourse to the argument that such an humble portion of the universe as ours, could never have been the object of such high and distinguishing attentions as Christianity had assigned to it. God would not have manifested Himself in the flesh for the salvation of so paltry a world. Forgetting that while the telescope led one to a system in every star, the *microscope* led to a world in every atom! And that while He gives insufferable heat to every sun, He delicately pencils the outline of the smallest flower.

'Why should He not care for His own? You know that for the possession of a very small and insulated territory, the mightiest empires of the world have put forth all their resources; and on some fields of mustering competition have monarchs met, and embarked for victory all the pride of a country's rank, and all the flower and strength of a country's population. The solitary island around which so many fleets are hovering, and on the shores of which so many armed men are descending as to an arena of hostility, may well wonder at its own unlooked-for estimation. But other principles are animating the battles: and the glory of nations is at stake; and a much higher result is in the contemplation of each party than the gain of so humble an acquirement as the primary object of the war; and honour, dearer to many a bosom than existence, is now the interest on which so much blood and so much treasure is expended; and the stirring spirit of emulation has now got hold of the combatants: and thus amid all the insignificance which attaches to the

origin of the contest, do both the eagerness and the extent of it, receive from the constitution of our nature, their most full and adequate explanation.

'Now, if this be also the principle of higher natures —if, on the one hand, God be jealous of His honour; and, on the other hand, there be proud and exalted spirits who scowl defiance at Him and at His monarchy—if, on the side of heaven there be an angelic host rallying around the standard of loyalty, who flee with alacrity at the bidding of the Almighty who are devoted to His glory, and feel a rejoicing interest in the evolution of His counsels; and if on the side of hell, there is a sullen front of resistance, a hate and malice inextinguishable, an unequalled daring of revenge to baffle the wisdom of the Eternal, to arrest His hand and defeat His purpose—then let the material prize of victory be insignificant as it may, it is the victory in itself which upholds the impulse of this keen and stimulated rivalry. If, by the sagacity of one infernal mind, a single planet has been seduced from its allegiance, and been brought under the ascendancy of him who is called "the god of this world"; and if the errand on which our Redeemer came, was to destroy the works of the devil—then let this planet have all the littleness which astronomy has assigned to it—it has become the theatre of such a competition, as may have all the energies and all the desires of a divided universe embarked upon it. It involves in it other objects than the single recovery of our species. It decides higher questions. It stands linked with the *supremacy* of GOD.' (Cheers.)

Mr Marsden's motion was put and carried, and after my reply, the members separated.

* * *

The Meeting was accounted a complete success, and on my way home, the Rev. Dr Whewell and Sir John Herschel accompanying me, we engaged in conversation.

Said Dr Whewell: 'I was pleased with the religious tone imported by Marsden and Chalmers.

I maintain the question, "Can'st thou by searching find out God?" must silence the boastings of science as well as the repinings of adversity. Indeed, science shows us, far more clearly than the conceptions of everyday reason, at what an immeasurable distance we are from any faculty of conceiving *how* the universe, material and moral, is the work of the Deity. But with regard to the material world, we can at least go so far as this; we can perceive that events are brought about, not by insulated interpositions of Divine power exerted in each particular case, but by the establishment of general laws. This is the view of the universe proper to science.'

'True', said I, 'and you will remember that Clarke, the friend and disciple of Newton, puts it, "All things which we commonly say are the effects of the natural powers of matter, and laws of motion, are indeed, speaking strictly, the effects of God's acting upon matter continually and at every moment, either immediately by Himself or mediately by some created being." Consequently, said he, there is no such thing as the course of Nature, or the power of Nature, independent of the effects produced by the will of God.'

'Far be it from us', interposed Sir John Herschel, 'to think otherwise. We would in no way be understood to deny the constant exercise of His direct power in maintaining the system of Nature; or the ultimate emanation of every energy which material agents exert from His immediate will, acting in conformity with His own laws.'

'Certainly not', replied the Doctor; 'I was rather showing how strongly does Science represent God to us as incomprehensible! His attributes as unfathomable! His power, His wisdom, His goodness, all that He is, is *infinite*. We cannot get behind His laws; indeed we cannot understand His laws. But other laws more complex will yet be unfolded to the plodders of Science. Still, we are glad to admit, with Bacon, that the ways and proceedings of God with *Spirits* are not included in Nature;

that is in the laws of heaven and earth, but are reserved to the law of His secret will and grace.'

'Ah! that is it', said Herschel; 'it is revelation that man wanted, for Pascal once said that he might or might not find God through Science, but if he did, such knowledge without Jesus Christ would be useless and sterile.'

Said the Doctor: 'And this God is our God for ever and ever.'

At this moment we proposed separating, but chancing to meet the Rev. Dr Sumner (afterwards Bishop of London), we rehearsed to him some of our talk, and on his invitation repaired to his home.

'To your interesting problem', said he, 'one of these three answers must necessarily be returned:

I. Either the world must have existed from eternity the same;

II. Or it was formed by chance, at some unassigned period out of pre-existing materials;

III. Or it was created by an omnipotent and intelligent Being.

'The question of the eternity of the world is strictly a metaphysical one, and can only be met by metaphysical arguments. Whether we suppose our globe to be 6,000,000 or 6,000 years old, it is of all truths that depend upon reason the most obvious, that something must have existed from eternity. Perhaps this is the only truth established by metaphysics which no sophist has been subtle enough to impugn. It is not, therefore, surprising that the apparent simplicity of supposing the world itself to have been that eternal thing, should have disposed philosophers to the early adoption of such a tenet.

'Locke reminds us that the reason why a stone falls to the ground, and the reason why the globe of the earth turns on its axis are equally to be

found in the book of Nature. But we have to face this: that there is matter and mind. Man and other animals have the power of moving themselves; while mere matter is certainly incapable of spontaneous motion. There is, therefore, two sorts of beings in the world, cogitative and incogitative, corporeal and spiritual. To agree with the eternity of the world hypothesis, the motion of a stone ought either to be *voluntary*, or that of a man, and other living animals, to be *necessary*, and determined by prescribed laws; and I conclude that in whatever way we view the matter, there are insurmountable difficulties opposing us, until we admit the agency of an intelligent immaterial Creator, whose presence in the system at once dispels the cloud, and diffuses the only light which on a subject so far removed from our comprehensions as the creation of the world, our minds are capable of receiving.

'Then if not in itself eternal did the world come by chance? We will do well to remember that in human work nothing is ever left to chance. The most experienced carpenter is the one who makes most constant use of his rule; the oldest mason keeps his wall in the perpendicular by his line. It is impossible, ninety-nine times in a hundred, to make a complete circle or a perfect square without the use of instruments. It is the result of our uniform experience, that no certain effect can be obtained without some regular means of contrivance. And whatever part of the universe we examine, from the minutest insect to the noblest animal, from the meanest plant to that magnificent system which the researches of modern astronomers unfold, we trace the undoubted evidence of *means* corresponding to their intended object, and attaining their end.

'We must, indeed, renounce all consistency of principle, unless we infer that this world, in which we see so many complicated and various means all conspiring to accomplish the best purposes, so many springs of action and motion, all coinciding in the most perfect order, was produced, and only could be produced according to the regular design of an

intelligent Being. As Paley well puts it, "He that cannot discover any traces of *contrivance* in the formation of an eye will probably retain his atheism at the end of a whole system of physiology."

'Then, thirdly, if I do not weary you, suppose the world really to have been the work of a Divine Creator, and man, of all created beings alone gifted with intelligence, and alone able to hold any connection with his intelligent Creator. It follows we must look to them as the chief objects of creation, and it is difficult to comprehend that intelligent beings were summoned into life, and then immediately abandoned by their Maker; and if we reject this idea, as inconsistent with all reasoning as to the probable operations of Divine intelligence, then it becomes almost necessary to conclude that the Creator would leave some memorial of Himself in a world which, as forming a part in the comprehensive scheme of His providence, He beholds with regard and interest.

'That such a memorial exists in the history given us by Moses I need hardly remind you, and all necessity of argument respecting the existence of a supreme Creator is of course precluded, if this history is admitted to be true. And the sacred writers who followed him, extending over no less than 1,200 years, speak of and for the Creator in the same sublime tone and language; from the earliest to the latest there is no contradiction. All the writers seem to have imbibed from the same fountain the same idea.

'From the sacred writers we obtain not only revelation but rules for life and *laws*, and I affirm in full confidence that every just research into the laws by which the moral man is regulated, as well as every fresh discovery in the constitution of the natural world, will tend eventually to illustrate the majesty of that Being, whose eternal counsels direct the whole, and from whom the will and power to search out those counsels ultimately proceed.'

* * *

We none of us attempted any interruption while Dr Sumner was speaking, and on separating we expressed surprise and satisfaction that a meeting so unpretending and convened as much for pleasure as for profit, should have led to the discussion and elucidation of themes so lofty and momentous.

Before retiring that night I reached down a volume from my bookcase and read:

'Science demonstrates incessant past changes, but the idea of a *beginning*, or of *creation*, in the sense of the original operation of the Divine volition to constitute nature and matter is beyond the province of physical *philosophy*, it can only belong to that of *faith*, and find expression in the language of inspiration.

'But though we know not the beginning, nor can foresee the end, yet LAW and ORDER existed before, and will continue after, HARMONY and SYMMETRY are permanent and eternal—the archtypes of the Divine plan — the very impress of that supreme REASON and "WISDOM", which was set up from everlasting; the Divine LOGOS of the Christian Genesis, who "was in the beginning", and without whom was not anything made that was made.'

CHAPTER XXIII

DIFFICULTIES ONE HAS TO OVERCOME

THE Amateur Astronomer is well satisfied if he can observe the phases of the planets, and follow to some extent the movements of the moon, the movements, maybe, of other satellites, resolve a few of the double stars and what not, and gather an amount of book knowledge of many other matters.

To attain more than this, one requires the

assistance of perfect instruments and a mastery of Mathematics.

I propose to mention here a few of the difficulties astronomers have to face: notably, Refraction, Aberration, Precession and Nutation, the exact Pole, Meridian, the Ecliptic and the equator on the Celestial sphere.

When at work at my observatory you will remember how I noticed that Polaris was not quite *fixed*, and to find the exact pole I must first note the highest point attained, and twelve hours later the lowest point—exactly half-way between will be the true pole. Any circumpolar star so treated will also give the true pole. If we reflect that the pole completes a large circuit of the heavens in 25,000 years, we will see that the true pole belongs to no one star but is always shifting along its circle.

Ninety degrees from the true pole we arrive at the celestial equator—the equinoctial.

The inclination of the pole, or axis of the earth, is found to be $23\frac{1}{2}$ degrees, so it necessarily follows that the ecliptic—the apparent path of the sun—varies to $23\frac{1}{2}$ degrees likewise. At the Winter solstice, December 21st, he is below the equator by that amount, and we in England only catch his slant rays; at the Summer solstice, in June, he is $23\frac{1}{2}$ degrees above the equator, and we enjoy his more direct light and heat; in *ascending* or *descending*, he must necessarily cut the equator, at the Spring and Autumn equinoxes, then, being directly over the centre of the earth we have equal day and night all the globe over.

Now observe, at the Spring equinox, the sun crosses the line, and his first 'second' of North Declination takes place, which momentarily increases until it reaches $23\frac{1}{2}$ degrees on June 21st; it then commences to decrease until the Autumnal equinox, when there is no declination, day and night are once more equal, the South declination begins and continues until $23\frac{1}{2}$ degrees is attained in December.

It has long been known that the sun comes to the equator half-yearly, sooner by twenty-five seconds of

longitude than on the preceding occasion ; this causes all the stars to recede by that amount. This retrogression of the stars—this precession of the equinoxes, accounts for the shifting of the pole of the heavens, and is one thing astronomers have to allow for.

A meridian is a line (invisible, of course), immediately overhead, that joins the pole with the equator, the first meridian, or zero, being reckoned as at Greenwich. A terrestrial meridian may be, say, 5, 10, 25, or any number of degrees East or West of Greenwich, but on the Celestial sphere the degrees are reckoned one way only, so that a star 1 degree to the East of Greenwich, looking north, would be said to have 359 degrees of *right ascension*, because it had travelled all the way, less 1 degree, from zero.

Whilst precession is understood, and right ascension is invariable, it has been observed that the pole, and hence all other stars, are raised or lowered by nutation, which matter has also to be reckoned with.

The fact that the earth is moving, and consequently the observer with it, produces another difficulty. When I pointed my glass at a star, I was content, in that I was noting its individuality, brightness, single or double, colour and so forth ; but the practical astronomer had to admit that in consequence of his own motion, his instrument had to be directed to the rear of the star in order to catch his ray of light, at the instant his own motion brought him in line with the ray. This difficulty, called the aberration of light, has to be allowed for.

Worse than all the foregoing comes the difficulty of refraction. Even I, amateur as I was, could not avoid this trouble. I noticed that the configuration of the constellations suffered distortion when near the horizon, being generally enlarged, whilst at the zenith they were compacted together. The fact is, the air surrounding our globe is never in the same condition long together, being at times rarer, at times denser. It is always denser near the horizon and when we look through it side-ways. Its refractive

powers vary from 33′ at the horizon to nothing at the zenith. This is a big difficulty that has to be reckoned with.

Below I give a drawing showing how the atmosphere which surrounds us in layers of varying density refracts or bends the rays of light as they pass through. When I looked through my glass at a star and thought I had located it, I was really pointing my instrument so many seconds away from the real position of the luminous body, according to its altitude, its light being bent by the air. Although I was able to view the star, I did not see it in its true place.

The moon has an apparent diameter of 31 *minutes*, therefore the displacement of a star by 31 *seconds* must be equivalent to a sixtieth of the moon's apparent diameter. I mention this that you may not think the displacement unduly excessive. Only at the horizon is it noticeable without instruments.

Parallax offers, especially in the case of the planets, another difficulty, because we view them from the surface of the earth and not from its centre, and all distances and positions should be reckoned as from centre to centre.

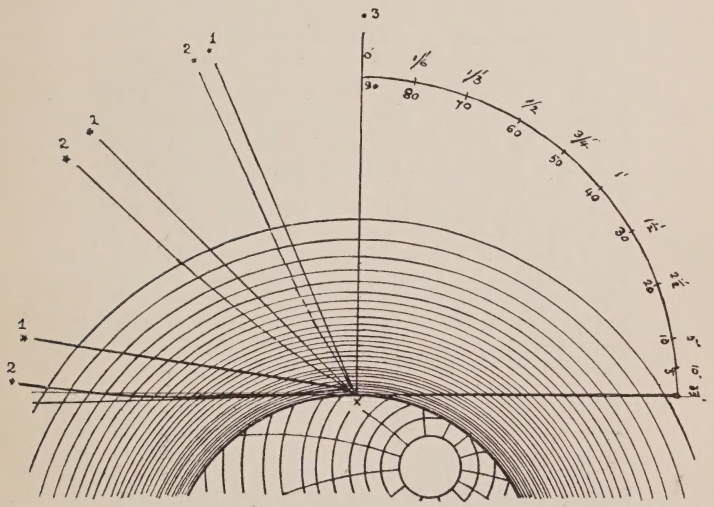
Seeing that all these difficulties are carefully allowed for, and that astronomers can predict occurrences such as eclipses, occultations of stars by the moon, and many other matters, as also conjunctions of planets one with another, or with the stars, I think we may place Astronomy among the exact sciences.

* * *

To detail the many matters calling for attention, which properly should have each a chapter, will far outstrip the aim of my story. To tell of conversations with such men as Norman Lockyer, Dr Huggins, Sir W. Crookes, or Sir Robert Ball would equally be far too gigantic an effort for my humble pages to enclose.

Still, as a brief consideration of many subjects hitherto untouched is quite necessary to an under-

standing of the merest outlines of astronomy in anything like completeness, I propose reproducing my attempt at a GLOSSARY, a sort of 'Multum in Parvo' that may perhaps induce my fellow students to enquire farther, and to search for details in larger treatises.



x Observer.
1 Apparent place of star, the atmosphere bending the rays.
2 True place of star.
3 No bending of rays at the Zenith.

CHAPTER XXIV

SOME ASTRONOMICAL TERMS

Items from Note Book arranged in the form of

A GLOSSARY

ABERRATION (of Light). Discovered by Dr Bradley, an Astronomer Royal. Light travelling with a great velocity, and leaving (say) a fixed star, may be seen through the tube of a telescope. But the telescope, partaking, as it must do with the motion of the earth in its orbit, it follows that we cannot see the star that sent forth that light in its true place. The ray travels *with the earth;* for half a year in one direction, and half a year back again. In exact terms *Aberration* is the effect of the progressive motion of light *compounded* with the annual motion of the earth. Observation shows that the stars appear to describe a minute copy of the ellipse travelled by the earth.

APHELION, is the greatest distance attained by any planet from the sun. PERIHELION is the position of any planet when nearest the sun. We see Jupiter or Saturn at times due South, and of course beyond us and away from the sun ; but it does not follow that either planet is then at Aphelion ; indeed they may be at that time nearest the sun. Should the earth be at her farthest distance and Jupiter at his nearest (although due South to us) his apparent diameter would be sensibly larger than at other times. At times the earth will be at Perihelion (or nearest to the sun) and Jupiter at Aphelion (or his farthest) at which time the greatest distance possible separates the two planets.

CO-LATITUDE is the complement or difference of 90 degrees. Thus if a star or planet is elevated above the horizon by 40 degrees the CO-LATITUDE is 50 degrees, because the total degrees between the horizon and zenith is 90.

COMETS. Very evanescent bodies, largely gaseous, that journey in various paths ; many of them attached to our system, but many more apparently having paths in space as if travelling from one system to another. Occasionally a large and brilliant one will appear in our skies, and its course may be noted for months,

when good practice can be obtained by amateurs in charting their journeys through the constellations. Halley's comet — so-called — referred to in Chapter IX, will soon afford such an opportunity.

Halley's comet, and a few others, describe long ellipses ; at perihelion just passing round our sun, often quite closely when the outward journey begins, the aphelion point not being reached until the orbits of the outermost planets have been passed. The one known as Halley's occupies 75 years in making one circuit.

Some comets visit us once and are seen no more. There are many hundreds so small as to need keen eyesight and telescopic aid. Most comets possess a streaming tail of light, behind a brighter and more solid nucleus. Apparently very little solidity exists, yet there is some for they confess allegiance to the power of gravitation. The behaviour of the tail in always moving directly away *from* the sun, suggests the action of solar electricity, which overpowers the action of gravitation on its lighter constituent parts. Very many smaller comets have no tails, and some without tails develop them on approaching the sun.

They remain, however, one of Nature's mysteries.

CULMINATION. A star or planet is said to culminate when at exact meridian, or when crossing the meridian of any given place.

DECOMPOSITION OF LIGHT (see Light, c).

ECLIPSE. The hiding of the sun by the moon passing in front, or between the sun and our earth. If the whole disc of the sun is obscured it is called a total eclipse ; if a portion of the sun only, it is called a *partial* eclipse. At times the sun is nearer to us by about 4,000,000 miles — if at that time when the sun appears larger the moon happens to be farther from us than at other times (by reason of her elliptical orbit), and an eclipse[1] takes place, we see what is called an *annular eclipse*, that is the moon not appearing quite as large as the sun, a ring appears all round the moon, the centre being hidden by the bulk of our satellite. The moon is said to be eclipsed when the shadow of the earth obscures her light. The fact of a lunar eclipse lasting some time conclusively proves her to be much smaller than the earth, should such proof be wanting. The shadow of the earth being cast by the sun must of necessity be smaller than the earth, until it reaches a point, yet at the moon's distance the shadow is sufficiently broad wholly to engulf her with a large margin to spare.

[1] Supposing it would otherwise have been a total one (Editor).

ECLIPTIC. A great circle in which the sun always appears to move ; so named because eclipses happen when the moon is in the circle (for total) or near the circle (for partial).

ECLIPTIC (Obliquity of) is the angle it presents with the equator. The amount of obliquity steadily progresses and after many ages returns. At present it is about 23° 28′.

EROS. A Planetoid (No. 433), discovered by Herr Witt of Berlin in 1893. It is remarkable that this last discovered world—about 17 miles in diameter—sometimes approaches the earth within 13,000,000 miles ; Venus the next, rarely within 25,000,000. It is thought that this little globe, as it is so near, will enable astronomers to ascertain more nearly, the exact distance of the sun, and hence all other planetary distances. This little brother planet, about the size of the Isle of Wight, has been revolving in his orbit all unknown for countless ages.

EQUATION (of time). The difference between equal and apparent time. A true clock shows the one—a sun-dial the other.

EQUINOXES. The two points where the equator and the ecliptic cross each other—March and September—the times when day and night are equal all over the world.

GALAXY (see Milky-Way).

GRAVITATION. The subtle something, observed but not understood, inherent in all matter, whereby one mass attracts another mass towards itself. The sun would draw the planet to himself, but for the planet's onward movement. The planets (puny things) would, and do in a small measure draw the sun. The earth draws the moon and the moon the earth, and the moon draws the waters of the earth, because they are mobile, and raises a tide, and draws the nearer part of the earth from the more distant waters and so effects a high tide at our antipodes, and indeed even affects the molten interior of our earth, for when the moon is nearest us, volcanic disturbances are most rife.

GRAVITY (Centre of). The point between two bodies calculated according to the several masses. Two equal bodies will have the centre mid-way. If one larger and one smaller, the centre of gravity will lie nearer the larger body. See page 117.

HELIACAL. Risings and setting. Denotes the act of a star or planet rising just before, or setting just after, the sun.

HORIZON. The visible one, i.e., the boundary of our vision is called the SENSIBLE horizon; the line dividing the upper hemisphere from the lower hemisphere is called the RATIONAL horizon. The sensible horizon will vary according to the altitude of the observer—the rational is parallel to it, but always half the globe. The sun and moon appear to set and are lost to view but some time elapses before they reach the true (rational) horizon.

LIGHT. Did it ever occur to you that you have never seen light? We observe things that are *in* the light. In olden time it was thought that the eye had the power to reach out, as it were, as though with an arm, and lay hold upon distant objects. Then it was averred that light consisted of emanations from luminous bodies, called the theory of corpuscles, but the accepted theory now is the *undulatory*. In speaking of *sound*, so also is it correct to say waves of light. Light travels in tiny waves from the luminous body, across intervening space, filled with ether or what not, for a resisting medium is almost certainly known to pervade all space;[1] much as the little waves do along the surface of agitated water. There are above 500,000,000 vibrations, or tiny waves per second. We see the actual combustion, say, in the common gas lamp, and in the glowing sun, but we see nought of its passage, nothing indeed until its journey is stopped. The object stopping the ray, reflects the same, and so becomes visible.

(a) VELOCITY OF LIGHT:

It has been proved that light travels at about 185,000 miles in a second of time; electricity alone travels at a greater speed, unless we allow first place to *thought*.

(b) INTENSITY OF LIGHT:

This varies according to the square of the distance in the direct ratio *towards* the source, and inversely *away* from the source.

(c) DECOMPOSITION OF LIGHT:

If a ray of light is allowed to pass, first through a narrow slit and then through a prism, of wedge shape, it will emerge in separated colours; violet, indigo, blue, green, yellow, orange, red, the first because they suffer refraction most, the subsequent ones, in the order given, being refracted in a lesser degree. By an instrument called the spectroscope, scientists can tell what metals and gases are resident in sun and star and nebula, by certain sure sign, never varying, in this method of discomposing a ray of light.

[1] *Almost* certainly, for some now believe space to be quite vacant.

(d) DAYLIGHT:

The time between sunrise and sunset.

(e) TWILIGHT:

From sunset until the sun is about 15 degrees below the horizon, and before sunrise when the sun has approached within 15 degrees of the horizon and its appearance. This rule slightly varies for different parts of the globe.

(f) MOONLIGHT:

Which is simply sunlight reflected back from our satellite; in intensity it is only a 600,000th of sunlight. Now when we consider that the whole expanse of sky could not contain 600,000 moons, even though placed in close conjunction, we gather, that were the whole heavens nothing but moons, we should still have less light than from our one sun.

(g) STAR LIGHT:

The stars shine by native light as does our sun. An attempt has been made to sum up the total amount of light given out on a cloudless and moonless night, with but small exactitude. Means, however, have been devised to determine the relative amount emitted by many individual stars, by noting the penetrating power when various membranes of a very thin substance are superposed. It has been calculated that Sirius shines where he is 192 times as brightly as our sun.

(h) ZODIACAL LIGHT:

The name given to a faint luminous appearance, in the neighbourhood of the sun, most often seen in the spring, and shortly after sunset. At times it almost equals the milky-way for brightness. It is thought to be a mass of minute meteors encircling the sun and revolving round him, but frankly no one truly knows how to account for the light. It is somewhat alike to Saturn's ring, for it always occupies the same position; we are so situated that we see it edgewise, and it is so extensive as to reach almost, if not quite, as far as the earth's orbit; Mercury and Venus at any rate pass through it continually. If it were anything but very attenuated matter, it would necessarily impede their motion and tend to lessen their annual journeys, which we do not observe to be the case. If it is an extended atmosphere of the sun, it is peculiar that it is so narrow, and always in the same plane. It is one of Nature's mysteries, and the young astronomer will view it with wonder, even if he cannot help to elucidate the phenomenon.

MILKY-WAY. A luminous track; an irregular band that appears to engirdle the whole heavens, of a whitish colour,

and which the telescope proves to be redundant in stars: Hence sometimes called the GALAXY. Astronomers have decided that it is really our own metropolitan collection of stars; that our solar system is a member of the collection, and that in all probability, many of the nebula, visible in our best glasses, are similar galaxies at incredible distances from our own.

MOON. Our well-known satellite. Less than a quarter of a million miles distant we can learn a great deal of her by telescopic examination. The well-defined markings reveal the fact that her surface is very mountainous, the very shadows of which may be seen and traced, varying in length as the eminences present different angles to the light of the sun. Huge craters of long since extinct volcanoes, and extensive plains, all of which have been mapped and named. It is very interesting to observe the moon when a few days old, that is, when little more than the merest crescent, and to notice how one after another the peaks catch the sunlight and so come into view. The observers at the great Lick Observatory were rather alarmed, early in the twentieth century, by the discovery of a crack, fully 80 miles long, lest some violent disruption was in process; but it was thought that as it was only to be seen at a certain angle, it might well have existed for ages, and yet have escaped notice. The moon travels round the earth in an elliptical orbit, so that she is sometimes nearer to us, and sometimes farther off; when nearest she is said to be in perigee, and when farthest, in apogee, that is near *geo*, the earth, and from *geo*. When nearer to our globe her motion is quicker than when at a greater distance. When the moon is *full* she is farther from the sun, and his attraction less than when she is new, because then she is nearly half a million miles nearer to him. It will not be a matter of surprise therefore that the lunar motions are very complex. Yet they have been thoroughly mastered.

The moon always presents to us the same face. In fact she turns round herself *once* in the same time that she takes to go once round the earth. She performs each revolution in about $27\frac{1}{4}$ days, but to us she appears to do so in about $29\frac{1}{2}$ days. That is because we are travelling as well, consequently she has to overtake us, which takes the extra time. She is always lightened by the sun as a full moon, and when we see her partially illuminated, the rest of the bright part is part of that portion we can never see.

The $29\frac{1}{2}$ days is called a *lunation*, and it has been found that after 235 lunations which occupies nearly 19 years, they are repeated on the same days; so that all the eclipses that are noted are repeated likewise, in the

same order. This is called the *Metonic Cycle*, and serves as a rule in fixing the time of Easter.[1]

NADIR (see Zenith).

NEBULÆ. The name given to the many cloudy patches seen through our telescopes—some few indeed by the naked eye. Many of them, by means of the spectroscope, are proved to be masses of glowing gas. The solar system, it is supposed, was once such a mass of gas, from which the globes and sun we now know were evolved. Many of the nearer nebulæ appear to be solar systems in the making. Others under powerful instruments reveal clusters of stars innumerable and may not be so *very*, VERY, far off, such as the Hyades, the Pleiades and others. Some others, not so resolvable, such as the well-known nebula in Orion, are so extensive as to dwarf our Milky-Way into insignificance: these are veritable UNIVERSES, but larger than our own! On this assumption, and it is considered certainly the case, the nearest *galaxy* must be situated no less than *five hundred million billions* of miles away! Light travels at the rate of 186,000 miles per second, THEREFORE that nebula must have been in existence at least 90,000,000 years ago.[2]

NUTATION. Any one wishing to study cause and effect will do well to study nutation. It belongs really to the great principle of universal gravitation. A child playing with scales and weights will observe that a pound weight in one pan will weigh equally with sixteen ounce weights in the other pan. Let him remove one of the ounce weights and the pound weight falls instantly. Nutation is a variety of this principle.

The earth bulges at the equator, that is, there is more matter there than at the poles. When we remember that the moon is sometimes above, and sometimes below, the equator, we can understand that, by virtue of gravitation it has power to slightly tilt the whole axis of the earth, first one way, then the other way. This action continues at each lunation, but since 235 lunations happen before they coincide (see above) it follows that the earth's axis will for 19 years describe a wavy journey in completing the circle, and so also, describes a minute ellipse in the background of the sky.

PERIHELION (see Aphelion).

PRECESSION. An effect, quite similar to nutation, caused by the sun. In consequence of the inclination of the

[1] There was no full moon in February (28 days) 1866. This unique omission will not occur again for more than 2,000,000 years.

[2] We are therefore looking at its past—its real condition to-day will not be known until 90,000,000 years have passed away!

earth's axis, the protuberances at the equator is presented to the sun in opposite directions twice yearly, as in the case of the moon, twice monthly. The result is that the sun crosses the equinoctial point earlier than it would if the equator coincided with the ecliptic, or path of the sun, thence the expression, *precession* of the *equinoxes*.

(a) The extent of precession is about 50.1″ each year.

(b) As a result the *signs* of the Zodiac *recede* that amount each year.

(c) The entire retrocession of the signs, in consequence of the precession of the equinoxes, occupies no less than 25,868 years.

(d) A large circle is described in consequence, by the axis of the earth, in that period, so that the pole star of one age is supplanted by another, in a subsequent age. Now it is the end star in Ursa Minor, later it will be *Vega*, later *a Draconis*, and later still our own polar star once again.

(e) The action of the moon and sun is sometimes in harmony and sometimes antagonistic, but the mean result is as stated above.

PROJECTILE. An arrow, a stone, or a bullet, impelled by a force is said to be a projectile. Such bodies always return to the earth by the power of gravitation. It has been calculated that were a body impelled with an initial velocity of 7 miles in the first second, such a body would never return to the earth, but continue for ever in its course unless, or until, stopped by some other body, such as a planet or star.

SHOOTING STARS. Small bodies that enter our atmosphere and become incandescent by reason of the friction of the passage, are in many cases supposed to belong to, or to have been detached from, the tail of a comet. Many thousands of these tiny bodies, and some are smaller than marbles, fall towards the earth every year, hardly any night but some may be seen. Most of them are entirely consumed before reaching the ground, where they simply deposit in dust. Those that are too large, are found on examination to consist of stone metal and specimens are exhibited in our National Museums. The special interest attaching to the phenomena is that on certain nights, notably in August and November, a far larger number than usual are to be seen, and it is conjectured that at those times the earth in its orbit crosses the paths of certain comets and captures the lagging members.

STARS. It is estimated that between 2,000 and 3,000 at most are visible to the naked eye. Sir Robert Ball thinks there are at least 100,000,000 stars in the universe. Ptolemy classified the stars into constellations, naming forty-eight such, but now over a hundred are charted, the brightest star in each constellation being known by the Greek *a*, the second brightest by the Greek *b*, and so on. The spectroscope teaches us that—(1) The stars are composed of gases and metals much the same as our sun. (2) Reveals the fact of their movement; some toward us, some away from us. The telescope shows that many stars that appear individual globes are really two or more stars in positive association with each other as binary or multiple systems. Stars with a white light are brighter and hotter than those shining with a ruddy light, and presumably the latter are older globes than the former.

Sirius is an example of a very bright star. It weighs something like three ordinary stars, but its brilliancy is seventy-fold. How do we know its weight? This leads to another question—*Do we see planets belonging to other systems?* In 1862 Alvan Clark discovered that Sirius had a companion revolving with him in little short of 50 years. It emits only 1-10,000th the amount of light its primary does, some of it probably native, and some perhaps reflected. By their action on one another *we weigh them.*

Algol, the variable star, is thought to have a huge satellite that periodically hides the light of its primary.

SUN. The centre and mainspring of the Solar System. His diameter 865,000 miles, his mass 330,000 times that of the earth; his velocity in space 154,000,000 miles per annum; his temperature (problematical) 18,000 degrees. He is subject to violent magnetic storms, and his surface is often torn in rents, as witness the sun spots, so-called; a curious feature being that they increase from minima to maxima in $5\frac{1}{2}$ years, and then decreases again in another $5\frac{1}{2}$ years from the greatest to least disturbance. This is not understood, but it is certain that the magnetism of the earth responds to the eleven-year period. The sun's rays and heat are responsible for the life, activity and beauty found in our own globe, as well as for all attendant planets. It is found that the sun is subject to compression to the extent of about 4 miles in a century, and it is thought that this contraction is the means whereby his heat is maintained.

TELESCOPES. These have advanced towards perfection as science has enabled manufacturers to provide the lenses. Therein lies the great difficulty. The speculum of Lord Rosse's telescope, weighing *three tons*, required six weeks grinding, with the force of a three horse-power engine, to

obtain the proper surface. This instrument when finished was the wonder of all.

In 1888, however, it was the fortune of the Americans to obtain, through the generosity of Mr C. T. Yerkes, a much larger one, the object glass of which is no less than 40 inches in diameter and the process of grinding and polishing required the labour of four years. It enables one to see the moon as if but 60 miles distant.

In 1900 a still larger one was made for the Paris Exhibition with a 49-inch glass; but months are required for the glass alone, and the cost exceeds £3,000 and the difficulty very great.

We are indebted to these large instruments for our knowledge of the satellites of Mars—for the fifth—(an inner one) of Jupiter, and in 1905 for the discovery of the sixth and seventh at about six times the distance of No. IV from its primary.

TIDES.—The waters of the sea rise and fall twice daily. Knowing what we do of gravitation and attraction, we can easily account for the phenomena. The water is mobile, and more readily answers to the *pulling* of the moon than does the solid earth. The sun does an amount of *pulling* as well, so when sun and moon are in conjunction (or opposition) we have *spring tides*, that is, very high tides; when the moon is at first or last quarter, we have *neap tides*, that is, not so high, for sun and moon pull different ways. The moon, although a small body, attracts most because of her nearness. It has been demonstrated that tidal friction will eventually alter the rate of diurnal rotation until the day is equal to the lunar one: but how many million years that will require scientists are unable to estimate.

ZENITH. That point of the heavens immediately over our heads. The opposite point, immediately under our feet is called NADIR.

ZODIAC. A Zone of the heavens, embracing 9 degrees on either side of the ecliptic (the apparent path of the sun). In this band, 18 degrees wide, nearly all the planets pursue their journeys. Twelve constellations will be seen to occupy the whole circuit side by side in the following order, and each constellation is apportioned 30 degrees and are called the signs of the Zodiac:

♈	*Aries*	The Lamb	
♉	*Taurus*	„ Bull	
♊	*Gemini*	„ Twins	
♋	*Cancer*	„ Crab	
♌	*Leo*	„ Lion	
♍	*Virgo*	„ Virgin	
♎	*Libra*	The Scales	
♏	*Scorpio*	„ Scorpion	
♐	*Sagittarius*	„ Archer	
♑	*Capricornus*	„ Goat	
♒	*Aquarius*	„ Water-Bearer	
♓	*Pisces*	„ Fishes	

ZODIACAL LIGHT (see Light, h).

ZONE. A girdle or belt. Such as the torrid zone, or temperate zone of the earth, or any similar portion of a planet or of the space of sky.

CHAPTER XXV

MEASURING THE HEAVENS WITH A SIX-FOOT RULE

SITUATED where we are, we can see with the naked eye, more of the Solar System than is possible anywhere else, with eyes of the same power.

At times it is just possible to see Uranus, so that with the exception of Neptune all the principal bodies are observable without telescopic aid.

An observer at Jupiter would be unable to see the earth in consequence of our nearness to the sun, whilst Neptune would still be outside his range of vision. At Saturn, the range of view would be still more limited; and a Uranian would see only Saturn at all clearly, Neptune would be seen occasionally, but it is doubtful if Jupiter, the giant planet, would ever come within view.

Our extensive knowledge of the bodies in space, is due to the telescope above all else. Its penetrating power dissolving the very nebula into countless hosts of stars, and enabling us, not only to see the invisible, but to tell their weights, and of what substances they are composed.

We have seen how many determined efforts have been made to ascertain distances. We may now call to mind that all measurements are comparative with the initial unit. Thus, in measuring London, say, we talk of a mile; the city is so many miles long, wide, and so forth. Having a map of Middlesex we can fairly well determine its area, having respect to the

known extent of London. It would be vastly more difficult to measure a map of England, however, because our London would have shrunken to a dot; and essaying to measure a map of Europe, we should utterly fail.

It is exactly so with CELESTIAL WEIGHTS AND MEASURES. Our proximity to the moon enables us to measure her because we can use the radius of the earth as a unit; measuring the sun, the unit is of very little use; and when we come to measure the distances of the stars we endeavour to use, as a base, the orbit of the earth, with, however, only scanty result.

While, however, certain results are attainable, we are lost in the matter of comprehending what we have learned. Astronomers, therefore, substituted the *speed of light per second* as a unit, in place of so many millions or billions of miles. In its turn that expression gave way to the almost illimitable one of the *light journey of a year.* Light travels 18,000 miles, ten times over, in every second. In a year light travels over 6,000,000,000,000 miles; and it takes nearly five years at that rate for light to reach us from the nearer stars.

What shall we say? What *can* we say? The mind refuses to comprehend numbers so stupendous! Hold! Stay!! Enough!!!

The Chairman is calling on me to commence my

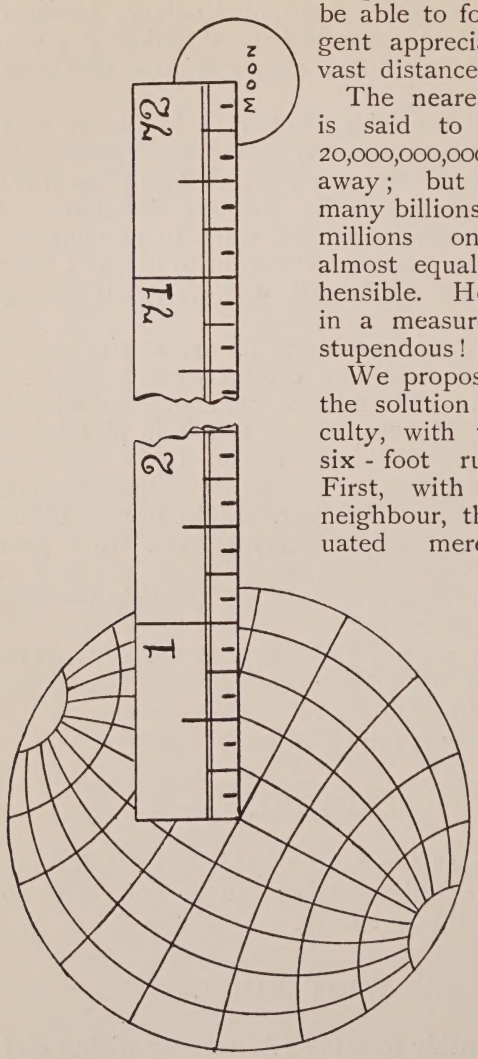
LECTURE

with the title at the head of this chapter for my subject; so we will see what can be done with so humble an instrument as a

SIX-FOOT RULE.

It is our monthly meeting (Astronomy night), and I commence by remarking, in accordance with the above reflections, that it was one thing to be told on credible authority that Neptune is distant

2,745,420,000 miles; it was quite another thing to be able to form an intelligent appreciation of the vast distance.

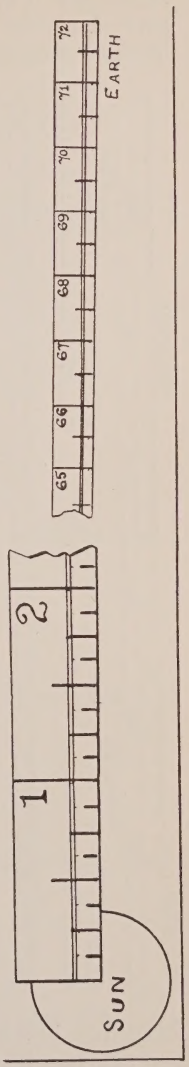


The nearest fixed star is said to be at least 20,000,000,000,000 miles away; but whether so many billions, or so many millions only, it was almost equally incomprehensible. How to grasp in a measure figures so stupendous!

We propose to attempt the solution of the difficulty, with the aid of a six-foot rule, dealing: First, with our nearest neighbour, the moon, situated merely 238,000 miles from the earth.

Let us commence with a description of our measuring rule. There are of course six prime divisions of one foot each. These are again divided into twelve inches, and each inch sub-divided into eight parts: so that we have:— $6 \times 12 \times 8 = 576$. Our rule has 576 units of one-eighths of an inch.

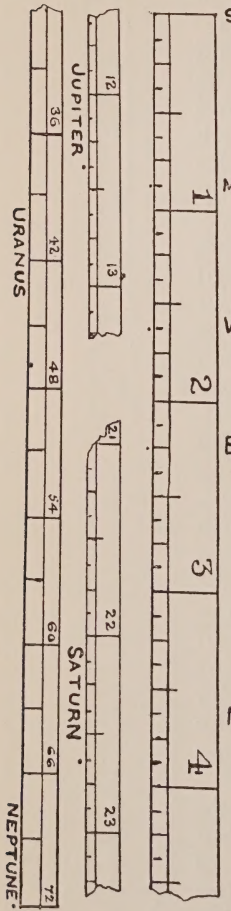
We will now, suppose, place the centre of the earth on the first line of the first inch, and the centre of the moon on the last line of the seventy-second inch. The distance of the moon being known, we must divide 238,000 by 576, the number of our units, and the quotient $413\frac{1}{3}$ will give the actual number of miles represented by each unit. Therefore were each one-eighth of an inch $413\frac{1}{3}$ miles long, our measure would exactly span the distance separating Mother-Earth from the centre of Luna-land. The comparative dimensions of the two globes will complete our task. The diameter of the earth is 7,916 miles, and that of the moon 2,160 miles; the radius being respectively 3,958 and 1,080.



We now take our compasses and mark off the respective circles having regard to the supposition each division is 413 miles. To the earth circle, give $9\frac{1}{2}$ units; to the moon circle, $2\frac{1}{2}$ units, and we have for result the drawing as above; so a globe, having a diameter of $2\frac{3}{8}$ths inches will stand for the earth, and one with a diameter of $\frac{5}{8}$ths will stand for the moon; our six-foot rule separating the two.

(2) Let us now measure the earth-sun system. The same rule, but the unit is now the 576th part of the sun's distance—92,000,000 miles—which we find by simple division to be 158,000 nearly; therefore, 576 units of 158,000 miles each would span the distance from earth to sun. As the sun is 850,000 miles in diameter, we must allow him about

$5\frac{1}{2}$ units, that is $2\frac{3}{4}$ for the semi-diameter, to properly represent him on our scale; and for the earth's semi-diameter of 3,958 miles we must allow—what? Well, we must divide a one-eighth unit into 39 parts, and one such 39th part will be allotted to the earth—the moon we cannot see.



(3) Our rule must now suffer more compression; for in measuring the Solar System we must take in Neptune with his distance of nearly 2,900,000,000 miles. Dividing that distance by 576 we get 5,034,723 nearly; so in each of our units there are 5,000,000 miles.

Now let us place the constituent bodies on our rule. Placing the sun's centre on the first line, we allow for his semi-diameter of 425,000 miles ONE-TENTH of the first unit; a rather generous allowance.

Mercury must be put on the seventh line; Venus at one inch and five-eighths; earth two inches and a quarter; Mars at three inches and five-eighths; Jupiter twelve inches and three-eighths; Saturn twenty-two inches and five-eighths; Uranus forty-five inches; while Neptune takes last place—seventy-two inches—at end of the rule.

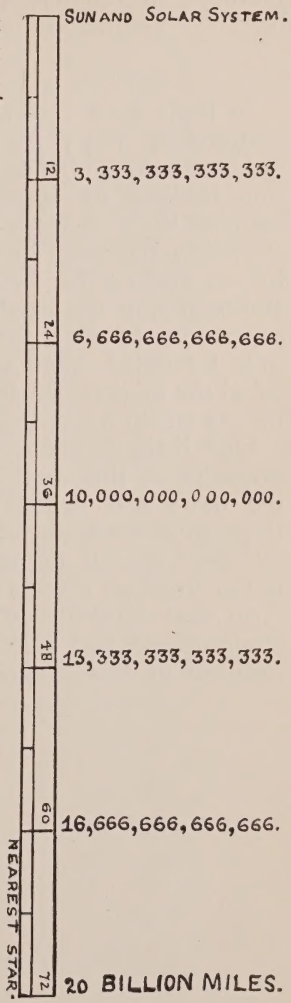
Should we wish to represent the planets as we have done above, we should procure the very finest

of pens, for Jupiter, the biggest of them all, will only occupy a 54th part of the unit on which he stands—Saturn a 66th part of the unit — and the magnificent globe we call our own, but a SIX HUNDRED AND TWENTY-FIFTH part of one-eighth of an inch.

* * *

(4) We will now try to finish our task, by finding where the nearest star comes in. It is doubtful if any star is nearer than *a Centauri*, in the Southern firmament, and the next nearest is *61 Cygni*, which is nearly twice as far off. *A Centauri*, however, gives a sensible parallax, and its distance is positively 20,000,000,000,000 miles away from the Solar System.

We therefore have to suppose the sun at the first line of unit No. 1, and the star at the final line of unit No. 576. Each unit in this case will represent 34,722,222,222 miles.



TRY IT FOR YOURSELF!

Our attempt to compare the Solar System with the Stellar world is a failure. Our blazing sun, with all his attendant planets; our world with all its pomp and show; with all its entrancing history; with all its hopes and

fears; with all its scientific attainments and knowledge; the very comets travellers that make their journeys in infinity, would all be lost in the faint line that commences our initial unit.

* * *

In reply to a vote of thanks, moved, I fear, in a perfunctory way; for in truth I had somewhat saddened my audience with my method of attenuation leading to apparent nothingness; I recommended them to work backwards again, leaving the star, view the more homely planets, then right home to sun and earth. Here we get warmth and light. But finally, in the earth and moon scale we feel our superiority at once, for are we not twice as heavy mile for mile? And whereas 300,000 earths would equal the mighty sun, it would need nearly 26,000,000 moons to do so.

One little moment, and I have done. There is disparity on this earth of ours. Who shall compare the moss and lichen with the giant oak, or the tiny mite with the leviathan? And whilst the telescope reveals for us the wonders that are afar, the microscope reveals a world in every atom. The Arm that built the starry skies, hath provided an environment just suited to the requirement of the meanest of His creatures.

TABLE

SHOWING

ELEMENTS OF SOLAR SYSTEM

Name and Symbol	Distance from SUN in Millions	Annual Period	Diameter (miles)
Sun ☉	...	...	845,000
Mercury ☿	35	88 days	3,050
Venus ♀	66	225 days	7,770
Earth ⊕	91	365 days	7,926
Mars ♂	139	686 days	4,155
Planetoids ⑤	250 375	3 Years to 6 ,,	230 and less
Jupiter ♃	475	11½ Years	86,936
Saturn ♄	871	29 Years	73,590
Uranus ♅	1753	84 Years	33,836
Neptune ♆	2745	164 Years	38,133

Apparent Diameter	Mass to Earth	Bulk to Earth	Velocity per Minute (miles)	Distance from Earth in Millions
31′ to 32′	316,560	1,216,750	350	91 to 93
5″ to 12″	.065	.057	1750	47 to 135
9″ to 61″	.786	.942	1283	23 to 159
...	1	1	1092	...
4″ to 18″	.118	.18	883	62 to 245
0.2″	?	$\frac{1}{42,000}$	600 etc.	...
30″ to 46″	302	1246	450	409 to 592
18″	90.4	730	333	831 to 1000
4″	15.5	70	242	1700 to 1900
2″	16.8	115	175	2630 to 2860

INDEX

INDEX

Names of Astronomers are shown in small capitals. Dates in brackets, the time they were prominent.

	PAGE
Aberration	135, 138
ADAMS, Prof. J. C. (1846)	90
AIRY, Sir G. (1840)	92
Angles	44, 86
Aphelion	138
Apocryphal planet	65
Apogee	143
Areameter, the	56
ARISTOTLE (B.C. 300)	22
Astral Diamond, the	83
Astronomical instruments	51
BACON (1600)	129
BALL, Sir ROBERT (present time)	124
Barometer, discovery of	36
Base line	44
BODE, J. E. (1801)	71
Bode's law	71
BRADLEY (1742)	138
BRAHE, TYCHO (1580)	15
BREWSTER, Sir D. (1850)	97
CHALLIS, Prof. (1846)	92
CHALMERS, Dr (1820)	127
Chance	131
Circles, great and small	9, 19
Co-latitude	138
Comets	43, 138
Constellations	76

NAME	SIGN	PRINCIPAL STAR
Andromada	———	Alpheratz
Aquarius	Water Bearer	Sadalmelik
Aquilla.	The Eagle	Altair
Aries	The Ram	Hamal
Auriga	The Wagoner	Capella
Bootes	The Hunter	Arcturus
Cancer	The Crab	(Crab Nebula)

Constellations — *Continued.*

NAME	SIGN	PRINCIPAL STAR
Canis Major.	Great Dog	Sirius
Canis Minor.	Little Dog	Procyon
Capricornus.	The Goat	Secunda Giedi
Cassiopeia	Lady in Chair	Schedar
Centaurus	———	A Centauri
Cetus	The Whale.	Mira
Cygnus	The Swan	"No. 61"
Draco	The Dragon	Thuban
Gemini	The Twins	Castor, Pollux
Hercules	———	Ras Algethi
Hydra	The Hydra.	Cor Hydra
Leo Major	Great Lion.	Regulus
Leo Minor	Little Lion.	δ Leonis
Libra	The Scales.	Zuben el Genubi
Lyra	The Harp	Vega
Orion	The Giant	Betelgeuse
Orphiuchus.	Serpent Holder	Ras Alhague
Pegasus	Flying Horse	Markab
Perseus	———	Algol
Pisces	The Fishes.	———
Sagittarius	The Archer.	Kaus Australis
Scorpio	The Scorpion	Antares
Serpens	The Serpent	Unukalhai
Taurus.	The Bull	Aldebaran
Ursa Major.	Great Bear.	Dubhe
Ursa Minor.	Little Bear.	Polaris
Virgo	The Virgin.	Spica

Contraction of the sun 146
Contrary forces 95
COPERNICUS (1500) 11
Creation of matter 130
CROOKES, Sir WM. (present time) 136
Culmination 139

Day: Astronomical 102
—— Commercial 102
—— Sidereal 103
Declination 135
Decomposition of light 141
Degrees 47
Deluge, the 126
Demon Star 84
Design, proofs of 131
DICK, Dr (1820) 119
Distances of the planets 63
Distances: how measured 47, 85, 148
Double stars 66

Earth a satellite 120
——, true diameter of 41
——, motion of the 113
Eclipse 9, 139
Ecliptic 140
Equation of time 140

PAGE

Equatorial instrument 54
Equinoxes 140
Eros 140
Eternity of matter 130
Exact pole, the 54

Fall of a stone 23
—— of the moon 39
Fictitious sun 103
First telescope 21
Fixed stars 87
Forces 24

Galaxy, the 140
GALLE, Dr (1846) 93
GALILEO (1620) 20, 26
Georgium Sidus 72
Gravitation 38, 140
Gravity, centre of 114, 140
Greenwich time 106

HALLEY, Dr (1700) 43
Heliacal 140
HERSCHELL, Sir WM. (1780) 66
——, Sir JOHN (1840) 128
Horizon 141

Inclination of the pole 134
Inertia 26, 91
Inexact Science 27
Instruments 52
'It moves for all that' 34

KEPLER (1600) 16
—— and Galileo 26
Kepler's laws 20

LA PLACE (1820) 98
Latitude 105
Laws of motion 25
Leap year 103
LE VERRIER (1846) 92
Light:—
  What it is 121, 141
  Velocity of 141
  Intensity of 141
  Decomposition of 141
  Daylight 142
  Twilight 142
  Moonlight 142
  Starlight 142
  Zodiacal light 142
LOCKYER, NORMAN (present time) 121

PAGE

Longitude 105
Lunation 143

Magnitudes of planets 57, 119
MARSDEN, Rev. T. (1850) 125
Mean sun 103
Measuring the heavens 148
Meridian 135
Meteoric shower 4, 145
—— stones 145
Milky-way 142
MITCHELL (1850) 104
Moon 143
—— eclipse of 10, 139
Moon's parallax 13, 45
'More worlds than one' 97
Motion, Rules of 25
——, relative 30
——, unsuspected 112
——, compound 113
—— of light 111
Motions of the planets 19

Nadir 144
Nautical Almanac 110
Nebulæ 144
Nebular hypothesis 98
Neptune, discovery of 93
——, weighing 94
NEWCOMBE, Prof. S. (present time) 118
NEWTON (1670) 37
Nodding 104, 144
Node, the 73
'No fixity' 87
Noon mark 52
NORDENSKJOLD, Prof. (1890) 124
NORMAN LOCKYER (present time) 121
Nutation 117, 144

Observatory 51
OLBERS, Dr (1802) 90
Orbits of the planets 28

PALEY, Dr (1785) 132
Parallax 44, 86
PASCAL (1650) 36, 130
Paths of the planets 29
Pendulum, the 33
Perigee 143
Perihelion 144
PIAZZI (1801) 90
PICARD (1670) 41
Planet-tracing 4, 18

PAGE

Planets:—
- Mercury . . 15, 57
- Venus . . 48, 58
- Earth . . . 119
- Mars . . . 61
- Planetoids . . 90
- Jupiter . . 62
- Saturn . . 62
- Uranus . . 72
- Neptune . . 94

Planets of other systems 146
Planets: relative sizes 63
Planetary time 104
'Plurality of worlds' 95
Practical Astronomy 51
Precession 144
Problem-solving 41
PROCTOR, RICHARD (1870) 118, 122
Projectile 145
Proofs of design 131
Proper motion 70
PTOLEMY (A.D. 160) 5

Quadrant, the 55

Radius 12
Rectification of the circle 12
Refraction 137
Relative motion 30
Rings of Saturn 62
ROEMER (1670) 111
Rules of Motion 25

Satellites:—
- Jupiter's 22, 110
- Mars' 100, 147
- Uranus' 92
- Neptune's 94

Shooting stars 4, 124, 145
Signs of the Zodiac 147
Six-foot rule 148
Size of the sun 89
SIZZI (1600) 27
Solar system: a lecture 57
Square of Pegasus 84
Stars (a few names of) 75, 146

- Alcyone
- Aldebaran
- Algol
- Altare
- Antare
- Arcturus
- Betelgeuse
- Capella
- Castor
- A Centauri
- Cor Hydra
- Denebola
- The Hyades
- The Pleiades
- The Pole Star
- Mira
- Pollux
- Procyon
- Regulus
- Rigel
- Spica
- Sirius
- Vega
- 61 Cygni

PAGE

Stars, age of 146
——, constitution of 123
——, double 66
——, how to read 75
——, number of 146
——, variable 123
——, new 123
——, temporary 123
——, circumpolar 76
Suction pump, the 35
SUMNER, Dr (1814) 130
Sun 146
—— contraction 146
—— source of energy 122
—— and star time 102
Sun's distance 47
—— journey in space 89

Telescopes 146
Telescopic wonders 21
'Tester,' the 69
Tidal friction 147
Tides 147
Time 101
TITIUS (1772) 71
TORRICELLI (1640) 33
Transit instrument 53
Transits of Venus 48
TYCHO BRAHE (1580) 15

Universal motion 87, 95
Uranus, moons of 92

Velocity 112
—— of light 111, 141

Weighing Neptune 94
WHEWELL, Dr (1850) 129
WITT, Herr (1893) 140

Zenith 147
Zodiac 147
Zodiacal light 148
Zone 148

1 million 87
20 billions 118, 153
100 million stars 146
25,868 years 114
90 million years 144

APPENDIX

Elements of the Solar System 155

Printed at
The Edinburgh Press
9 and 11 Young Street

UNIVERSITY OF TORONTO
LIBRARY

Do not
remove
the card
from this
Pocket.

Acme Library Card Pocket
Under Pat. "Ref. Index File."
Made by LIBRARY BUREAU